Volume 5 May, 1926 Number 5

JOURNAL

OF THE

AMERICAN WELDING SOCIETY

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33 West Thirty-ninth Street, New York

American Welding Society

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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 5 MAY, 1926 Number 5

ANNUAL MEETING

By far the most successful annual meeting of the American Welding Society was held in New York on April 21, 22 and 23. Starting off with well attended research sessions of the Gas Welding and Electric Arc Welding Committees on Wednesday, ample evidence was had that the work of the Society and its research department (the American Bureau of Welding) was appreciated by the welding industry. The Gas Welding Committee concentrated its attention in discussing a program of investigational work on the qualities of welds to be subjected to high temperature uses. The San Francisco Section of the American Welding Society has an active sub-committee in charge of this work. The Electric Arc Welding Committee discussed the results of a large series of tests started during the war which are now being completed to determine certain fundamentals of arc welding such as currents, size of electrodes, number of layers, design of joints, position of welding, etc.

The business session was held Thursday morning and included the President's report of the year's activities, financial report, membership report and election of officers. The President's report and recommendations aroused a spirited discussion. This report is printed elsewhere in this Journal. The financial report indicated that we are in a very healthy state financially, although larger funds from increased membership would allow the Society to enlarge its scope of activities. Various suggestions were made for increasing the membership of the Society.

In order to accommodate the members, a luncheon was arranged at the Engineers' Club which adjoins the Engineering Societies Building, on Thursday noon. All the reservations were sold out and it was necessary to supply extra space for a number of late comers. Professor C. A. Adams spoke at the luncheon of the work of the Electro-Technical Commission which was holding its meetings in New York.

The technical session was held on Thursday afternoon. The following papers were presented:

"Welding in the Design of Industrial and Power Piping," by L. J. Sforzini, engineering and maintenance department, Eastman Kodak Co.

"The Design and Manufacture of a Horizontal Cylindrical Pressure Tank," L. H. Burkhart, chief engineer, Struthers-Wells Co.

"Gas Welded Longitudinal Seams for Stringent Requirements," A. C. Vick, plant engineer, Detroit Range Boiler & Steel Barrel Co.

"The Design of Welded Joints," S. W. Miller, consulting engineer, Union Carbide and Carbon Research Laboratories.

"Design of Welded Joints in Ship Construction," J. W. Owens, director of welding, Newport News Shipbuilding & Dry Dock Company.

"Design of Welded Joints," E. E. Thum, manager publicity department Linde Air Products Company.

Very interesting discussion followed the presentation of each of these papers. This discussion will be printed in the June issue of the Journal. Members are cordially invited to send in additional written discussion of any of these papers.

The 1926 Annual Dinner Committee of the American Welding Society set a high standard for all future dinners of this nature. The dinner was held in the Rose Room of the Hotel Astor and was followed by a dance. A very interesting program of professional entertainment was enjoyed by everyone present. Through the courtesy of the Air Reduction Company, a liquid oxygen demonstration was also included. About 150 people attended this affair.

Probably the most interesting session of the Annual Meeting was held on Friday morning in connection with the annual meeting of the American Bureau of Welding. Although about 35 leading executives in the welding in-

dustry were invited to attend, there were nearly 100 people present. Four papers were presented on fundamental problems in the welding industry that should be considered in a research program. The discussion which followed the presentation of these papers indicated that there was an appreciation on the part of leading welding executives of the importance and value of such fundamental investigations.

On Friday afternoon there was scheduled an inspection trip to the plant of the Metal and Thermit Corporation and also a meeting of the board of directors of the Society. At the latter meeting appointments were made for officers and chairmen of standing committees of the Society. President Oehler's plan for the appointment of a part-time Technical Secretary was referred to the executive committee for consideration.

Those in attendance (over 300 people) were unanimous in their opinions that this Annual Meeting of the Society was the most successful in its history.

PRESIDENT'S ANNUAL REPORT 1925-1926

During the past year, contrary to custom, the activities of your president have been much like those of a king in a chess game, namely, to try in his feeble way to keep out of trouble, while the queen, the rooks, the bishops, the knights and the pawns carry on the work of the Society. With a little imagination it is not difficult to identify the various chess pieces among our membership. Not all can be queen, but there is need for more rooks, bishops and knights.

Fall Meetings

Outstanding among the accomplishments of the Society during the past year is the success of the fall meeting held in Boston, at which welding equipment was exhibited in operation. Over 5000 people inspected the exhibits. This meeting did much to show, to advertise, the possibilities in the welding field and to establish the importance of the Society in that field.

Arrangements are now well under way for holding another fall meeting of this kind in Buffalo and this meeting bids fair to rival the one held in Boston.

Cooperation with Other Societies

Welding is an adjunct to other branches of engineering and for this reason it is important that the American Welding Society cooperate with other engineering organizations.

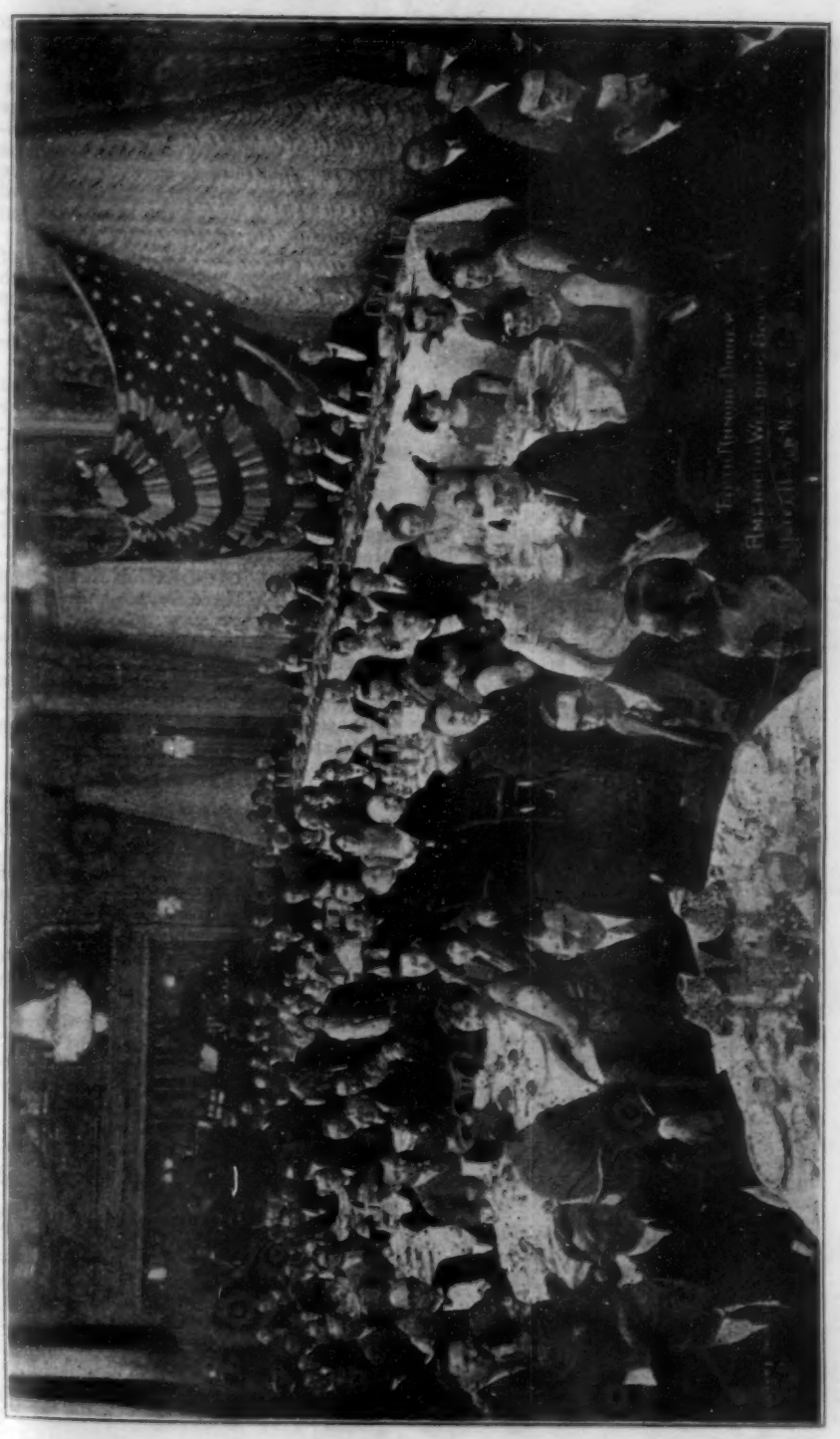
Much has already been done by the rail joint committee in conjunction with the American Electric Railway Association. The American Society of Mechanical Engineers, the American Welding Society and the American Bureau of Welding have agreed upon and laid plans for a joint investigation on unfired pressure vessels. This will undoubtedly be a valuable contribution to the industry and will involve an expenditure of $100,000 including cost of test specimens and materials. The American Welding Society has been asked to appoint representatives on American Engineering Standards Sectional Committees, one on safety code for machinery for compressing air and one on safety code for pressure piping. The International Acetylene Association and the Gas Products Association prepared a standard for hose connections which was approved by the American Welding Society. The welding committee of the Association of Railway Electrical Engineers has asked our cooperation in preparation of its annual report, but unfortunately our representatives were unable to go to Montreal at the time of the last meeting.

By-Laws

The by-laws of the Society have been amended and added to. These changes in substance provide that the dues for class D members residing elsewhere than in the United States, Canada and Mexico shall be $10 instead of $5, that students in trade schools and colleges can enjoy student membership with annual dues of $2.50, that sections will not receive the usual 50 per cent of dues in the case of student members, that a senior vice-president residing in the vicinity of headquarters shall be elected by the Society for a term of one year thus providing for six instead of five vice-presidents.

Legislation

On several occasions the Society has been asked for information and expression of opinion concerning proposed legislation which was considered by members to restrict the use of welding unduly. Without getting into politics the Society has supplied the information asked for and has assisted materially in preventing legislation which would retard industry and involve great and unnecessary



expense to manufacturers of welded products. In no case has the Society fostered the increase of welding applications at the expense of safety.

Arbitration

The possibilities of having the Society sponsor arbitration of disputes regarding contractual obligations has been studied by a special committee and it is probable that this investigation will be continued.

New Sections

The Portland section was organized on March 18, 1926. At a preliminary meeting held on that date, twenty applicants were made members and a total enrollment of 80 is expected.

The Los Angeles section was reorganized on Oct. 29, 1925, and has enjoyed considerable activity and a large increase in membership since that time.

Tentative plans have been laid for the formations of sections in St Louis, Atlanta and Kansas City.

N. A. Wright was appointed divisional vice-president of the Pacific Coast Division to succeed C. S. Smith, who resigned. In the Middle Western Division, Stuart Plumley was elected vice-president to take the place of H. S. Mann, who resigned.

Meetings and Papers Committee

R. L. Shepherd resigned as chairman of the meetings and papers committee and F. W. Swain was appointed in his place. This committee has done excellent work in arranging programs for the fall and annual meetings of the Society, in giving assistance to local sections and in laying out, after long and careful consideration, a policy covering editorial, technical and advertising material included in the Journal.

Membership

Membership in the Society has since April 1, 1925, been increased 5½ per cent. The total number of class D members has decreased but there has been a large increase of class B and class C members.

American Bureau of Welding

The work of the American Bureau of Welding continues as in the past to be one of the most outstanding accomplishments of progress of the American Welding Society. Five new society representatives, Henry Goldmark, Dr. A. D. Bisteen, C. J. Holslag, Dr. A. Krebs and A. M. Candy, were appointed to the Bureau to fill the places of inactive members dropped.

When the Bureau was first organized, it had affiliated with it a large number of sub-committees. Excellent work was done and gradually as reports were finished some of the minor sub-committees were discharged and activities have been concentrated on a few large important projects. In a printed report of the Division of Engineering of the National Research Council, which is now in press, the American Bureau of Welding is credited with having published 45 separate reports.

I am advised by the Director that more attention will be given to the consideration of fundamental researches in the welding field. As before stated, with the help of the National Research Council it has been possible definitely to secure the cooperation of the American Society of Mechanical Engineers in a comprehensive joint investigation in the field of welded pressure vessels. I believe this will mark a new era of development for the American Welding Society. Negotiations are under way to start a similar joint investigation in the welding of structural steel parts with the cooperation of the American Institute of Steel Construction.

Technical Secretary

The principal functions of the Society are: first to increase the knowledge of the art and science of welding and extend its applications, and second, to promote the interests of the industry. In its primary function the Society is succeeding admirably, but in my opinion there is need for more intimate contact between the Society and the welding industry. Several possible means for improving this contact have been investigated and I offer the one which seems most practicable for the consideration of the incoming executive committee.

The plan consists essentially of appointing W. Spraragen as technical secretary of the American Welding Society in addition to Miss M. M. Kelly, present administrative secretary, in which capacity he would work on the average one day a week. The income of the Society is such that about $1,500 a year might be spent for this work, $1,000 to cover traveling expenses and $500 for salary.

The duties of the technical secretary would be as follows:

1. To maintain contacts with the in-

dustry, make the American Welding Society better known and create a better understanding of the functions of the Society with relation to the industry.

2. To assist the membership committee through personal interviews with leading executives.

3. To visit sections, increase their activities, learn their needs and problems and help them arrange better meetings.

4. To help in the organization of new sections.

5. To discover important problems in industry and help in the extension of the use of welding.

6. To secure papers and advertising for the Journal and authors for section papers.

7. To get new active members on committees of both the Bureau and the Society through larger and better acquaintance with people in the welding industry.

8. To secure support for research projects.

9. To represent the American Welding Society at meetings of affiliated organizations.

10. To interest higher educational institutions in welding engineering.

11. To maintain a research information service.

ANNUAL REPORT

Meetings and Papers Committee

Functions:

The functions of the Meetings and Papers Committee continues to be as in the past:

1. To arrange the programs for the fall and annual meetings of the national society.

2. To assist the local sections of the American Welding Society in securing suitable speakers for their meetings.

3. Determination of policy in connection with editorial, technical and advertising material included in the JOURNAL of the Society.

Fall Meeting:

A novel feature was inaugurated during the last fall meeting of the Society held in Boston, namely the showing of welding exhibits. Due largely to the efforts of the local Boston Committee, it was possible to make this first venture a remarkable success in attendance, character of the meeting and financial aspects. A great deal of the time was given over to technical papers on very timely subjects. The attendance at these several sessions indicated strongly that with careful preparation, these technical sessions can be made outstanding events. In addition, there was a dinner, theater party, a meeting of the American Bureau of Welding and special features in connection with the exhibits.

Annual Meeting:

The program for the annual meeting has already been reported to the members. The only novel features are the shortening of the business session and the holding of a high-class Dinner Dance.

Local Section Programs:

The national committee has been able to render assistance during the past year to many of the local sections in arranging suitable programs. Special attention was given by the Committee in rendering assistance to the Western Coast sections. Success in this direction indicates the desirability of continuing to foster such an interchange of information between the East and the West.

Policies:

An effort has been made by the Meetings and Papers Committee to formulate policies governing the acceptance and publication of papers in the JOURNAL of the Society and cooperation with trade papers. Definite rules have been formulated which the Committee believes will be of assistance in expediting its work. These have been submitted to the Change in By-Laws Committee for their consideration.

Journal:

A comparison of the number of printed pages of the JOURNAL for 1925 with the year 1924 is very interesting and is therefore reproduced below:

	1924 pages	1925 pages
Editorial	96	108
Technical	494	585
Advertising and circular matter	222	239
	812	932

Although the JOURNAL of the Society continues to be a profitable undertaking financially, nevertheless it is hoped by the Meetings and Papers Committee that membership of the Society will be increased to such an extent that the funds derived from advertising and from the sale of the

JOURNAL may be used in enhancing its value. Moreover, larger circulation will also increase its value as an advertising medium.

The present state of the finances of the Society does not warrant the Meetings and Papers Committee requesting an increased appropriation for publication expenses, although such an increase would enable the Committee through the Editor of the JOURNAL to inaugurate some additional sections in the JOURNAL so that it might be more useful to the industry. However, even with the present limited funds an attempt will be made to enlarge the current welding literature column through arrangements with the Engineering Societies' library.

The Meetings and Papers Committee have not as yet completely solved the problem of obtaining thorough discussion of the various papers printed in the JOURNAL, although some success has been attained in connection with the papers presented at the annual and fall meetings of the Society. It is urged that this problem be given the most careful consideration by local section officers.

Respectfully submitted,
P. W. Swain,
Chairman Meetings and
Papers Committee.

NEW OFFICERS AMERICAN WELDING SOCIETY

At the annual meeting held on April 22, the following officers were elected to serve for the coming year:

President. F. M. Farmer, Chief Engineer, Electrical Testing Laboratories.

Senior Vice-President, E. M. T. Ryder, Way Engineer, Third Avenue Railway System.

Vice-Presidents representing New York and New England Division, R. L. Browne, District Sales Manager, Metal and Thermit Corporation. Middle Eastern Division, A. M. Candy, Commercial Engineer, Westinghouse Electric & Manufacturing Co. Middle Western Division, Stuart Plumley, Editor, Acetylene Journal.

Directors at large, for three years, C. A. Adams, Pierce Hall, Harvard University; A. B. Bissell, Westinghouse Electric & Manufacturing Co.; A. G. Gaynor, J. A. Roebling Sons Company; H. M. Hobart, General Electric Company.

At the meeting of the board of directors, held on the afternoon of Friday, April 23, the following officers and chairmen of standing committees were appointed:

Secretary, M. M. Kelly.

Treasurer and Chairman of Finance Committee, C. A. McCune.

Meetings and Papers Committee, P. W. Swain.

By-Laws Committee, A. M. Candy.

Membership, J. J. Flaherty.

DISCUSSION OF PAPERS

Papers presented at the annual meeting of the American Welding Society were printed in the April issue of the Journal, and one of them, by Mr. Thum, in the May issue. The Meetings and Papers Committee cordially invites any member who was unable to attend to prepare a written discussion of any of these papers. These written discussions will be included with the oral discussions and will be printed in the June issue.

WELDING STILL UNDEVELOPED IN APPLICATION

(Copied from editorial appearing in March 13, 1926 issue of Electrical World. Applies equally to Gas and Resistance Welding.)

Electric welding has become an accepted tool in many industries. Thanks to the war, it gained a standing which it has been able to maintain and expand; but there remain many unexploited fields of application. Too many engineers consider welding to be a process to apply to small repair jobs, spot-welding jobs in manufacturing and possible "showy" applications to fabrication work for electrical machines. The truth is that the use of welding to make motors, generators and turbo-generators has been adopted because the process makes for a lighter, stronger, less bulky and generally cheaper job.

As a matter of considered opinion the big fields for welding have not been exploited in any degree. Careful investigators consider that electric welding can compete successfully with any methods for fabricating steel. The tall steel skyscrapers with their innumerable riveted joints should be considered as splendid prospects for welding applications. Metal containers of all kinds, steel marine vessels, substation structures, piping of all types, railroad rails and bonds, transmission towers, cranes and hoist

structures and other big steel fabrications in industry are well within the field of application of electric welding. Engineers and contractors may be trusted to study the welding process more fully, for it has economic and engineering merit or it would not have withstood the fire of commercial competition. Utility power salesmen also are sure to study electric welding carefully in order to encourage its greater use by their customers.

INTERNATIONAL WELDING AND CUTTING EXPOSITION

Rapid progress is being made by the Buffalo section in arranging for a very large exhibition of materials fabricated by welding, including a model building. The exhibition will be held in conjunction with the annual fall meeting of the Society on November 15 to 20.

The Meetings and Papers Committee are planning to arrange for very high-class technical sessions so that a program will be secured which will result in the greatest fall meeting ever held by the American Welding Society. Members should make their plans now to attend.

AN ELECTRICALLY WELDED COMMERCIAL BUILDING

(*Reprinted from April* 10, 1926, *issue Electrical World*)

More than once attention has been called in these columns to the desirability of using electric welding in the fabrication of steel structures and in their erection. It is therefore with particular satisfaction that we have read papers by H. P. Egan and P. A. Storm (*American Welding Society Journal*, January, 1926, Vol. V, pages 51 to 66) describing a building which was completely arc-welded. The heavy-duty structure, 100 feet by 150 feet, is a two-story-and-basement commercial building, and 95 tons of structural steel were entirely welded by the arc process, both in shop fabrication and in erection.

Although originally designed for rivets, the structural work was awarded on a competitive basis to a company which offered a welding method, on the plea of a more satisfactory job. The factor of safety is claimed to have been nearly doubled as compared with riveted joints. A consideration of importance is quietness in doing the work. With riveting the constant rap of the pneumatic hammer is a source of annoyance and of loss of patronage to adjacent hotels and stores. The owners and the builders of the structure are to be congratulated upon their progressiveness and courage in adopting a comparatively new method of joining steel parts under stress. It is to be hoped that this pioneer building will be followed by many other electrically welded structures of larger size and of greater importance, until riveted joints will be seen only in museums devoted to a history of engineering art.

1926 INSPECTION TRIP

On the afternoon of Friday, April 23, about 30 members of the Society journeyed to Jersey City, where they were met by buses and taken to the Jersey City plant of the Metal & Thermit Corp. Unfortunately this inspection trip occurred on the same afternoon as the meeting of the old and new Board of Directors of the Society, so that many were unable to attend.

At the plant the visitors were shown through the offices, the Chemical Laboratory, the Research Laboratory, the arrangements for the handling of specimens and the taking of photomicrographs, etc., and it was explained that most of the physical testing work was done at Stevens Institute of Tech., whose physical laboratory was conveniently located.

From the offices the visitors passed down through the plant by the Tungsten buildings and boiler house to the Foundry building, where they watched the making of several small welds which were part of the jobbing work of this department. Here, also, they were shown the making of a modern Thermit rail weld from start to finish and the making of 1¼ in. extra heavy and 4½ in. extra heavy pipe welds. In the Thermit building members watched the various steps of the manufacture of Thermit, being particularly impressed with the extreme care necessary to produce a uniform product—the blending of the seven oxides according to their physical and chemical analysis, the furnace treatments and the chemical control of this operation, the careful weighing and mixing of the ingredients through automatic weighing machines checked on delicate equal-arm balances, and the final physical and chemical testing of the mixture.

The party then visited the Machine Shop building, in which are manufactured the Rail Preheaters and Shop Preheaters, and in which all the maintenance and repair work of the plant is carried on. From here they went in the Metal manufacturing building, and the arrangements for the making of the large "buttons" of the rarer metals by alumino thermic production was explained.

From the Metal building they went into the Chromium Plating building, which is one of the newer developments of the Metal & Thermit Corp. and which, together with the exhibit of chromium plated articles, was one of the most interesting features of the trip.

After the usual refreshments and cigars the party disbanded about 5 p. m.

SECTION ACTIVITIES

New York

The May meeting will be held on the 18th and will be the last meeting before the summer vacation. A Get-Together Smoker will be provided for this occasion, at which time C. J. Holslag, manager of the Electric Arc Cutting & Welding Company, will discuss the electric welding of the new stainless steels and demonstrate his remarks by exhibition of samples, and George L. Walker, assistant research engineer of the Air Reduction Company, will give an illustrated talk on "Gas Welding of Tool Steel."

San Francisco

The annual meeting of this section was held on the 16th. C. E. Rhein, district sales manager of the Linde Air Products Company, gave an illustrated talk on "Procedure Control in Welding Pressure Vessels."

Chicago

The American Brass Company presented a motion picture entitled from "Mine to Consumer," at the March meeting of this section, which was held on the 5th. The subject of bronze welding was also discussed.

The April meeting was held on the 22d. C. A. McCune, past president of the Society and research engineer of the American Chain Company, presented an interesting and instructive talk on welding wire. This address was illustrated with motion pictures and lantern slides showing the manufacture of wire from the open hearth furnace to the finished product. An exhibition of the suitability of the flame test in detecting bad welding wire was also shown by Mr. McCune through actual samples of good and bad welding wire secured from different parts of the country.

The May meeting was held on the 7th, at which time G. O. Carter, consulting engineer of the Linde Air Products Company, presented a review of good practice in preparation of joints for welding and various jigs, fixtures and shop tools which may be employed to secure the best results in welding.

Cleveland

The annual meeting of the section was held on April 20 in the Engineering Rooms of the Hotel Winton. A. F. Davis, of the Lincoln Electric Company, presented a paper on the "Welding of a Crane Runway," recently built by the Morgan Engineering Company. A number of slides were shown in this connection, and also on the arc welding of steel parts to replace grey iron castings.

Boston

The Boston section held their regular meeting at Massachusetts Institute of Technology in connection with the Mechanical Engineering Society. Prof. Kinsey gave a very interesting talk on "Fusion Welding."

Make your plans to attend Annual Fall Meeting

AMERICAN WELDING SOCIETY

Buffalo, Nov. 17-19, 1926

EMPLOYMENT SERVICE BULLETIN

Opportunities.—The Society is glad to learn of desirable opportunities from responsible sources, announcements of which will be published without charge in the BULLETIN.

Services Available.—Under this heading brief announcements (not more than seventy-five words in length) will be published without charge to members. Announcements will not be repeated except upon request received after an interval of three months; during this period, names and records will remain in the office reference files.

Note.—Copy for publication in the BULLETIN should reach the Society's Office not later than the thirtieth of the month if publication in the following issue is desired. *ALL REPLIES should be addressed to the number indicated in each case and mailed to Society headquarters.*

POSITIONS VACANT

V-31. Salesmen and Estimator wanted. Required by one of the largest and best established job welding concerns in New York. Preferably a man who has experience or one who has a fair knowledge of welding, both gas and arc, and who is accustomed to doing business with large service stations and fleet owners.

An interesting proposition will be made to the right man, which assures a good income on a salary and commission basis, to a live wire who can produce. All details will be treated in confidence.

V-32. Experienced welder or welding engineer wanted who has had broad experience in tank welding including bath boiler construction. In our Seamless Division we have decided to develop welding of certain types and styles of containers, and we want experienced man to follow work through various stages including testing.

V-33. Welder wanted with experience in electric arc and oxy-acetylene welding.

Services Available

A-41. Electric welder desires position. Have had 8 years' experience, including repair, machine and boiler work on the Erie R. R. and high pressure vessel and tank work of Standard Oil Co.

A-42. Electric welder desires position. Have had 10 years' experience, including six with the Tide Water Oil Co., three years with Standard Oil and one and one-half years with M. W. Kellogg Co.

A-43. Oxy-acetylene welder desires position. Have had five years' experience and can weld any kind of work, including aluminum.

A-44. Acetylene welder desires position. Have had seven years' railroad shop welding experience and four years' industrial welding. Desire position as Foreman or Supervisor. Have credentials as welder, also as instructor.

A-45. Oxy-acetylene welder desires position. Have had experience and can furnish reference.

A-46. Electric welder, 19 years' experience in shipyards, railway shops and general welding work. Employed as welder, demonstrator, instructor, engineer and supervisor. Drafting room and repair experience. Familiar with all the different makes of oxy-acetylene torches and regulators, and can make own repairs. Can furnish best of reference as to character and ability. Prefer to locate in Philadelphia.

A-47. Acetylene welder desires position. Has had 6 years' experience, including repair work, pipe and boiler construction. Can give references.

Fundamental Research in Welding

Many centuries ago an attempt was made to reduce the wisdom of the ages to a four word summary. The report of the scholars of this ancient convention is worthy of attention: "This, too, will change."

Let us examine the significance of this remark as applied to the welding industry. In a brief space of less than ten years we have seen the applications of welding extended to at least five times the former amount. If an accruate analysis could be made of the causes involved research would easily head the list. However, for the most part this research has been of the more practical kind, but we are rapidly approaching the time when further radical improvements can be made only as a result of fundamental research into the reason "why."

It has been found in the past that research in the fundamentals of various processes has met with some opposition because it was difficult, if not impossible, to see any immediate benefit from it to the industry involved; but in recent years so many instances have occurred in which such research has resulted in enormous savings both to the public and to the industry that the opposition referred to is very much decreased. It is fortunate that in the welding industry there appears to be very little of such opposition, and the members of the American Bureau of Welding believe that such research is not only necessary but profitable.

It is perfectly natural that industrial organizations should spend money on the solution of practical problems, because on these solutions depend commercial success. The work of such problems is of necessity in the hands of the industry and generally in a few concerns. On the other hand, fundamental research, which is actually beyond the means of any one company, not only as to diversity of talent needed, but also as to money and time, should be carried on by the whole industry under the auspices of any impartial organization Moreover, the cooperative effort, which brings to bear on the solution of a problem organized effort of many minds, is more likely to result in successful solution of complicated problems such as are met with in the study of the fundamentals of welding.

There follow four papers presented at the annual meeting of the American Bureau of Welding in an attempt to suggest a few of the fundamental welding problems. The Bureau invites written discussion of any of these papers in the hope that this will stimulate progress. We expect the industrial leaders connected with the American Welding Society to see the great needs of fundamental investigation and to support this work on a cooperative basis. The suggestion has been made that some, at least, of these investigations could be carried to a successful conclusion by research fellows working in our leading universities.

Research, the Beacon of Progress in Arc Welding*

H. M. HOBART† and W. SPRAGUE‡

About ten years ago arc welding was very little used as a commercial tool and its possibilities, to a great extent, were unrecognized. In the World War arc welding received its first great boost when it was used in the repair of the damaged interned liners. The necessity for speeding up production in our shipbuilding program led to the consideration of its possibilities in the construction of minor and major parts of ships.

Not much was then known about welding in a scientific or engineering way and a welding committee was organized under the Emergency Fleet Corporation to study the various problems involved. The greatest difficulty that confronted the committee was the fact that an air of mystery surrounded the whole subject. There were a number of welding operators who were considered as experts who could get good results. The reason why was not easily understood. The situation was rendered still more confusing by the fact that the methods used by these experts in getting good results differed materially. A research committee was appointed to endeavor to discover the reasons underlying these observed facts.

So little was known about the subject that this research committee merely had to scratch the surface, so to speak, in order to discover something which appeared really promising. The efforts of the committee were therefore very largely devoted to correlating of opinions and checking these up by tests whenever opinions seemed sufficiently diverging. Continued efforts by the committee and by other investigators along these lines repeatedly produced valuable results because it was not difficult to discover new truths. Under such stimulus, welding advanced rapidly. New applications were constantly being made. There came about a gradual standardization in the way of doing things that would yield satisfactory results even though the reason why was frequently not understood.

With these applications into newer fields and particularly into fields where life and property are at stake, it has become increasingly difficult to give satisfactory reasons why this or that result is obtained in practice. Engineers, legislators and scientific people interested, have requested proofs instead of opinions, and test results instead of merely service experience.

The properties of arc welds have become better known and their limitations as well as their capabilities have become more clearly

*Presented at the Annual Meeting of the American Bureau of Welding, New York, April 23, 1926. One of a series of four papers on suggested fundamental researches in welding.

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‡Secretary, Electric Arc Welding Committee.

defined. But even today the question of the "why" of things remains unanswered.

It is interesting to let the imagination picture what might happen if the reason why was understood. For example, ordinary arc welds made with any ordinary bare wire have always been recognized to be more or less brittle even though they possess quite satisfactory tensile strengths. The practical man immediately announced that the weld was a casting and that to expect it to possess qualities of the rolled parent metal was quite ridiculous. Some of our competent metallurgists, on the other hand, felt that they should know what made these welds so brittle. Microscopic examinations revealed liberal inclusions of oxides and nitrides which worried the practical man not at all. The research man viewed this information differently. He reasoned quite rightly that these undesirable constituents were formed in a very brief passage of the metal across the arc by contamination with the air at high temperatures. It was quite easy, therefore, to reason that something should be done to prevent such contamination. Some argued that the remedy was to be sought in fluxes administered in one or other of a variety of ways. Others argued that the welding should take place in other atmospheres than air. Both methods have been demonstrated to be more or less successful and now welds have been produced in the laboratory through welding in a hydrogen atmosphere which are as ductile as the parent material. Hence the statement of the practical man that an arc weld is a casting and must necessarily remain brittle and that to expect anything else would be ridiculous, is not altogether true.

The same reasoning would be used by the practical man for every item which could be mentioned not only in welding but in almost any process or industry.

Even in our present enlightened day we do not know how the metal is transferred across the arc in ordinary metal arc welding. The importance of the inventions and modifications in the present forms of welding which would certainly be made if this phenomenon was understood is easily imagined. On the other hand, the problem is not easy of solution. The heat of the arc is very intense. The transfer of the metal takes place in a very short time and in a very small space and is accompanied by glare and a profusion of ultra violet rays which make it mandatory to use protective glasses. Still a way should be found for studying this important subject. Mathematicians and physicists should get busy and try to allocate the distribution of energy involved, and the kind and amounts of magnetic forces. Our pyrometer experts might devise ways and means for studying the temperature gradient of the arc. There are many other kindred problems whose solution might affect this particular study and in themselves might offer great commercial possibilities. For example, the answers to the following questions might be helpful—

a. What is the effect of flux coating on the wire?
b. What effect have flux coverings in preventing contamination of the metal while it is being transferred across the arc from the welding wire to the work?
c. What are suitable flux coverings?
d. What is the effect of the chemical composition of the welding wire on the rate of transference of metal?
e. What impurities are burned out of the welding wire?
f. What impurities are transferred to the joint?
g. What is the effect of the grain structure of the wire on its suitability for use in the form of electrodes?
h. Can equally good welds be made with a long arc if a hydrogen atmosphere is used?
i. How can we tell without tests to destruction whether a weld is sound?
j. What takes place in overhead welding?

Some of these problems need to be studied by competent physicists and metallurgists. These should be farmed out to suitable universities. A suggestion has occurred to the authors that the American Bureau of Welding should offer one or two prizes for the best memoirs on the physics of the arc, including some of the points enumerated above. A first prize of several thousand dollars would be entirely warranted by the results which might be obtained. These are fundamental questions, the solution of which would undoubtedly yield immense returns on the funds invested for the conduct of their investigation. Success cannot, of course, always be assured in advance. On the other hand, there remain many practical problems which can be investigated in a statistical way by the compilation of practical test results and the analysis of these statistical results by suitable committees. Many of these practical problems will undoubtedly come up and will be answered in the proposed pressure-vessel investigation of the American Bureau of Welding. Some of them may also be answered in the series of tests at present under way which was started during the days of the Emergency Fleet Corporation.

In addition to these researches directed to ascertaining "what will occur," it is of importance to research for the "reason why" of known occurrences.

While the "reason why" is believed to be known in some of the following cases, there is room for divergence of opinion. Also in some cases in which a few able scientists understand the reason why, advantage would accrue through having it stated in language which can be comprehended by a larger circle of interested people:

1. Why can some kinds of bad welding wire be made good by dipping in lime?
2. Why can some kinds of good welding wire be made bad by polishing the surface, or by pickling?

3. Why is it possible to transfer carbon and manganese in certain wires and not in others?
4. Why are excellent welds obtained, especially as regards ductility, by using a surrounding atmosphere of hydrogen?
5. Why does hydrogen welding require a much higher arc voltage and a higher striking voltage than arc welding in air?
6. Why are excellent welds obtained, especially as regards ductility, by using a surrounding atmosphere consisting of mixtures of hydrogen and nitrogen with any proportion of nitrogen up to 75 per cent or more?
7. Why is the arc voltage, when the nitrogen considerably exceeds the hydrogen, very much lower than the arc voltage when welding in pure hydrogen?
8. Is it possible to eliminate the hardening zone next to the weld?

We are still asking questions and researching for the answers. To use the title of this paper, research is the beacon of progress in arc welding, as in everything else. We are, however, not decreasing the number of unanswered questions. When we obtain the answer to a question, that answer suggests new questions and new researches for their answers. Our progress is proportional to some power of the number of formulated but as yet unanswered questions.

In the last ten years tremendous progress has been made in arc welding and we have now many more formulated but unanswered questions than then. But we have been researching and obtaining answers to our questions at a constantly increasing rate. As compared with ten years ago, there are in all respects notable differences between the procedure employed in arc welding then and now. Possibly the most important progress in arc welding and that which has brought with it the greatest number of differences in procedure and results is that associated with the use of automatic arc welding machines. These machines are the results of combining the lessons learned from many different researches and they constitute an epoch making advance in the art of joining metals.

One serious difficulty which has tended to limit the amount of current, which it is practicable to use with manual welding, has been that the magnetic field set up by the current in the surrounding conductors affected the position of the arc. It was liable to be deflected laterally and in erratic ways. In some automatic machines an adjustable part of the current is carried through an insulated conductor located just below the chill bar. This current sets up a magnetic field of the right direction and which can be adjusted to the right length, to make the arc steady.

Incidentally the automatic arc welding machine is an admirable

aid to research. When comparing welds made under different conditions (which it is constantly necessary to do in research work), the human factor can be largely eliminated. The automatic machine does not pre-judge and then proceed to demonstrate the correctness of its pre-judgment. It is rigorously just and impartial. The best intentioned human being is unconsciously biased and cannot trust himself, still less others. The verdict of the automatic machine, however, is worthy of respect.

Before concluding, we wish to call attention to the necessity for employing standard tests as criterion of the quality of welds. It is useless to state that a sample made in some new way sustained millions of cycles of the stresses occasioned in a certain improved type of fatigue testing machine unless many comparable tests of known materials or welds made by other processes are available for comparison. The American Bureau of Welding has adopted standard tests for tensile strength, ductility, ageing, hardness, etc., and these should be followed in endeavoring to evaluate the welds made by new methods or procedures based on researches. Much expensive research has been completely wasted through evaluating the results in non-comparable expressions or ways. We share the researcher's distaste for tiresome quantitative tests but we admit their indispensability.

Some Unsolved Fundamental Gas Welding Problems*

S. W. MILLER†

I do not know that there are any such problems that are entirely unsolved, though there are many that need much more work on them. Of these I mention a few.

The first problem that occurs to me is, "Is there a true neutral welding flame, and if not, what is the closest approach that can be made to it?"

We are all accustomed to speak of a neutral flame as if it were a definite thing, and as if we had no trouble in producing it. It is true that there is a flame that we call "neutral" as defined by certain visual evidences, but I doubt that it is entirely neutral. There is difficulty in studying such a flame because of its exceedingly high temperature when oxygen and acetylene are used, or, in fact, when any gas is burned in the presence of pure oxygen. The only kind of attack that I can think of is with the spectroscope, and apparently some college whose laboratory is fitted with proper apparatus, and some of whose staff are familiar with spectroscopic work, would be the place to study the problem.

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The second problem is, "The strength of welds at higher temperatures," and as this involves considerable knowledge of practical welding, the attack on it should be made by a combination of those familiar with welding rods and their manufacture, and those who have the apparatus for testing steels at high temperatures. The general problem has been undertaken by the San Francisco section of the American Welding Society, and they understand that cooperation of others interested in the general problem should be secured.

Third, "Non-destructive tests for welds." Unfortunately some people have assumed that the whole status of welding depends on the solution of this problem, although such an assumption is entirely unwarranted. Indeed, the problem is more general than as stated because it applies to all forms of joints. I am at a loss as to how this problem should be attacked because there has been considerable work done on it by magnetic and electrical resistance methods, and by the X-ray, and the results so far obtained have been distinctly discouraging. It is true that by all three methods exceedingly bad welds can sometimes be detected, but such welds could never exist under competent supervision, beside which the cost of making the tests is prohibitive at present.

I think the best way to study the problem would be for some college to assign some competent man to review the work that has already been done, and to carry out further tests along the same lines, or along others that might be developed during the course of the study. It would be very interesting also to study at the same time other types of joints such as riveted and brazed, although we are not greatly interested in them.

Fourth, "Development of high strength welding rods." Welds made with the usual plain low carbon steel rod are rather low in tensile strength, say about 52,000 lb. per sq. in. of plate under the best conditions, and when not reinforced. Reinforced welds may run as high as 58,000 lb.

Evidently this is lower than desirable, as steel plate frequently has a strength of 65,000 lb. per sq. in.

Special rods have been developed that give, without reinforcement, about 67,000 lb. average tensile strength. While this is a great advance and allows the use of ordinary steel plate with the assurance that rupture will not occur in the weld, better results are desirable. This work should be left in the hands of commercial interests, who are willing to stand the expense, which is quite high.

Fifth, I would also mention the matter of procedure control, which is a real research problem and which will always be with us. Each case is sin generis, and must be considered from its own special conditions.

The points that must be controlled are:

1. Design.
2. Materials.
3. Test of operators.
4. Methods.
5. Supervision.
6. Tests of finished product.

Obviously if these are all worked out and applied properly, the results cannot fail to be good. I think the A. W. S. can do no better work for the industry than to insist on the development of this feature, so that failures of welded parts may be avoided.

As each case is special, it is not possible to write a general procedure control. But it might be that a special committee could be appointed in any instance, that would be competent to pass on the accuracy of a procedure control submitted. The details of the control would have to be worked out by the one submitting it, for the committee could not have the intimate knowledge of plant conditions necessary to its preparation.

Fifth, The best base metals for welding. This applies to nonferrous as well as ferrous metals, and much work has been done on it in the way of selecting good welding materials from among commercial products. There is no definite assurance, however, that there are not better materials than those at present available.

This is a very large problem and would require the cooperation of metal manufacturers, those skilled in welding and laboratories competent to make physical examinations of all kinds of metals. Of course steel is the most important metal and should be considered first.

Welding in the Structural Field*

J. H. EDWARDS†

The preparation of a statement of what seem to be some of the fundamental considerations to bring out the use of welding in the structural field is undertaken with the full realization that personally we know little about the science or art of welding. On the other hand, we endeavor to keep our minds open to learn about this or any other method of joining together component parts of a structure safely and economically. Perhaps for the reason that we know so little about the welding technique, but am acquainted with present day structural practice, we may be able to indicate without prejudice the things that the structural engineer and fabricator want to be shown.

The history of the evolution of any new art is that the new at first takes the old as the basic starting point. In other words, it is an evolution not a revolution. Ancient structures were held

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together by gravity and friction, or by cords and thongs in the way of lashings. Then pins through mortise joints, and finally, instead of one or a small number of pins, groups of small pins such as bolts or rivets were used. When the change from wood to combination wood and iron and then to all iron was being made some blacksmith-welding of iron was done, mostly of rods or bars. This was found unsatisfactory, so much so, that it was avoided, and when steel took the place of wrought iron specifications prohibited welding of steel.

Having painted somewhat of a background, we will now endeavor to give you the welding picture as the structural engineer sees it.

The points of special interest are:

a. The structural steel material used;
b. The welding operation;
c. Shop fabrication such as handling and assembling;
d. Cost.

MATERIAL

The kind of steel used for structures is fixed by the steel makers, and at the present time is usually rolled to suit the specifications adopted by the American Society for Testing Materials. The chemical contents are approximately Carbon 0.15 to 0.40; Mang. about 0.40; Phos. not over 0.06, and Sulphur not over 0.05. Using this standard material which structural engineers believe should be adhered to, can good welds be made? Furthermore, since there is a tendency to give consideration, in the case of special structures, to steel of higher strength, say average around 70,000 lb. tension, having a greater carbon content than standard structural, also steel of even higher tensile strength in the case of alloys, the structural engineer is naturally interested in knowing if these higher steels can be welded satisfactorily. If, as some now think, only steel of low carbon content and corresponding low ultimate strength, below 60,000 lb., can be safely welded, then much of the apparent saving by welding disappears when 65,000 lb. to 70,000 lb. steel can be fabricated in the usual way at no increase in cost over the lower grade. The efficiency of welded joints made in material of varying thickness, as well as the varying strength of joints, should be determined. That is, can a joint between material 1 in. thick be designed using the same unit factors as for material ¼ in. thick, and a joint carrying a stress of 100,000 lb. the same as one of 10,000 lb. stress?

There is doubt in the structural engineers' mind as to what effect the welding operation may have on the parent material. The usual assumption is made that the weld can be made as strong or stronger than the main material (we have seen some statements to the effect that it makes the main material stronger) although the natural assumption would be that welding may reduce the strength of the parent material adjacent to the weld. This should be set-

tled by comparative tests of plain and welded material. The strength of the parent material should not be assumed as that reported by the mills, but determined by tests of coupons cut from the same bar as the welded specimens.

WELDING

The type of apparatus or the method of making the weld is not of particular interest to structural steel fabricators, as long as the results obtained are satisfactory. The limits of welding operations and strength of welds should be determined and standardized. If resistance welding is considered, the area or extent of welds required to develop full strength of material should be learned and unit values fixed. If fusion method, gas or electric, is used, the character and amount of added material should be agreed upon and strength units fixed. Types of joints, such as lap and butt, should be studied and safe working values of the welds per unit under different conditions should be fixed for both static and dynamic loading.

If the welding is done by machine the mechanical control may possibly be made positive and uniform, but there exists in the minds of manufacturers much doubt about ability to obtain uniform results when the human element is such an important factor in fusion practice. The training and control of the individual welder, the one person on whom the integrity of the connection depends, is the element concerning which all doubt must be eliminated. As this is a mental or psychological rather than a physical or mechanical problem its solution in a convincing way will be difficult.

SHOP AND FIELD OPERATIONS

The shop operations, the so-called fabrication work, can best be determined by the manufacturers of structural products, rather than by makers of welding apparatus. The adaptation of welding to take the place of pins or rivets will no doubt progress step by step, making use as far as possible of material rolled to the present standard shapes, and of existing shop equipment. New and better suited shapes and methods will gradually find their economic place, probably not without some resistance on the part of shop men, evidencing a natural trait of human nature.

In all probability there will be a marked change in the design of types of structural members from those now in general use before riveted and bolted construction of this type can be displaced by welding. The solution of this problem will be the heritage of engineering representatives of purchasers and fabricators of structural steel.

The study and adoption of welding in making field connections of steel structures present a number of difficulties that are not met with in shop operations. Some of the outstanding difficulties to be met in the field are, the ever present element of tolerances and

clearances, the taking care of line, level and plumb, and the erection of large tonnage in very quick time.

The leaders of the steel fabricating industry, however, are willing to be shown and will welcome anything that has economic virtue. The great drawback, as we see it so far, has been the lack of fundamental scientific data on which the manufacturers could base their strength determinations. When these are given them they will willingly undertake to adapt their operations to new circumstances.

COST

The most important factor, after having satisfied the designer that welding can be safely done if certain well determined rules are applied and suitable methods adopted, is the cost. The study of production costs, like the development of shop methods, it seems to us, can best be done by the manufacturer of the finished product. There are so many connected and related operations to be considered besides the welding operation that the party interested in all should correlate these expenditures.

The cost of the operations may vary at different shops, and the shop management will adjust itself to the new conditions. Bad advice may be given by one not familiar with the manufacturers' individual product and the conditions of labor and mechanical equipment. The handling of plain material in preparation, jigs and clamps for holding the assembled parts, must all be studied and arranged to suit the class of work to be done. While the costs we have observed so far may cover the expenditures for actual welding, it is not apparent that due allowance has been made for the ever present "overhead" that must be included if profitable business is to obtain. Overhead exists and is variable, and must be fixed to suit shop conditions. Any cost statement that does not include it is looked upon with suspicion and is usually discarded by the careful manufacturer.

GENERAL

In conclusion I would make some general observations concerning the information so far available for use by the structural designer and fabricator. It has been of the most optimistic character, as it naturally must be coming from advocates of the use of a new method or process. It has been mostly sales talk. While statements made concerning the welding art have been probably true in part, observations about the related operations have shown much ignorance, and have tended to discredit the whole. Statements to the effect that for welded joints all members of structures should be in compression, that welding increases the strength of the main material and the odious comparisons of riveted and welded joints, are not taken seriously. Fabricators of structural steel from many years of experience have learned the virtues and weaknesses of rivets and know how to use them so as to make economical and safe structures. What they are seeking concerning welding

are the fundamental facts on which they may base their determinations of strength. When human life is in jeopardy one must be cautious. He must know the foundation on which he builds and be reasonably sure of the results obtained. To sum up, the fundamental considerations that the structural trade is waiting for are—

a. Can standard structural steel be satisfactorily welded and what are its limitations? If this grade of material is not suitable, what is?
b. What effect will the welding process have on the parent or main material?
c. Standard methods of making welds by different processes should be determined. Values on some unit basis for the strength of welds of different types should be fixed.
d. Some reliable way of controlling the mechanical and personal element in the making of welds and in testing the completed work should be established.

With this information fixed by scientific research and available to the industry, the manufacturers of welding apparatus, the advocates of welding as a method of joining steel parts, and the fabricators of structural steel, all cooperating to solve an engineering and economic problem, will doubtless make great progress in the development of the art of welding in the structural steel industry.

How to Investigate Welded Tanks*

H. L. WHITTEMORE†

Without doubt we are all agreed that our welded tanks are not entirely satisfactory.

If we are interested only in finding the strength of the tanks we are making, we can select tanks, preferably from stock, subject them to increasing pressure until they burst, then decide what is the safe working pressure for each. This is essentially *testing* and offers no great difficulties.

If, on the other hand, we wish to work out the best and most economical way to fabricate tanks, we must plan our work very differently—we must carry out an investigation. Efficient expenditure of our time and money are important considerations. We will, therefore, carefully follow the well-recognized principles which have proved their value in the past.

First—We will study all the available information relating to our investigation. Building and testing tanks is expensive business and it is inexcusable for anyone to repeat work which has been satisfactorily done by others. Recent numbers of the "Zeitschrift

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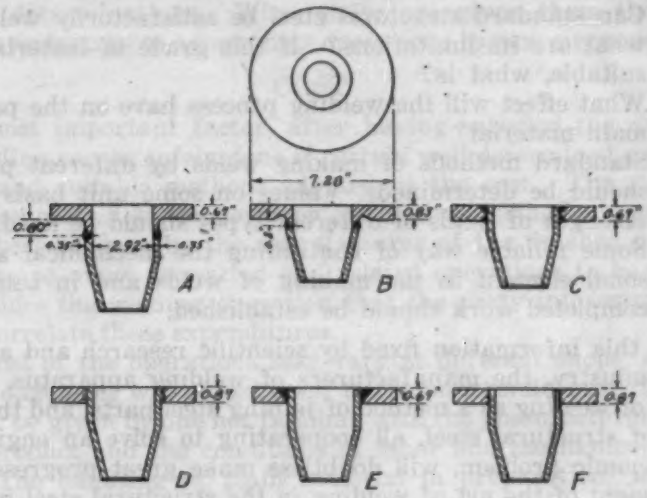
*Presented at the Annual Meeting of the American Bureau of Welding, New York, April 23, 1926. One of a series of four papers on suggested fundamental research in welding.

†Chief VI-5, Engineering Mechanical Section, Bureau of Standards.

des Vereins deutscher Ingenieure" describe investigations of welded tanks which have been in progress for a number of years in Europe. Apparently, this work has been done by a well-organized group of investigators who were unhampered by other problems.

Can we afford to rush into an investigation without translating the publications of these and other workers or without expending



	Average Strength For A Length of Weld lb / in.		Cross Section Adjacent To Weld. - Strength lb / in.²
A	2 Aut.	14360	40300
	1 Elec.	16900	47800
B	4 Aut.	10080	28500
	1 Elec.	—	—
C	18 Aut.	12300	34700
	1 Elec.	12340	34850
D	*	—	—
	4 Rolled	6260	17700
E	12 Aut.	5770	20900
	1 Elec.	10430	29450
F	*	—	—
	4 Thrd.	6720	19000

* Average Strength Computed For A 1" Length of Seam

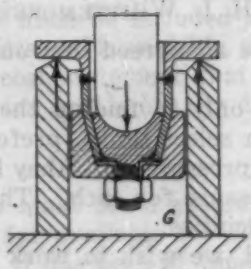


Fig. 1
Test Specimens and Fixtures for Tube Connections

A, B Welded Tubes
C, E
D Expanded Tubes
F Threaded Tubes

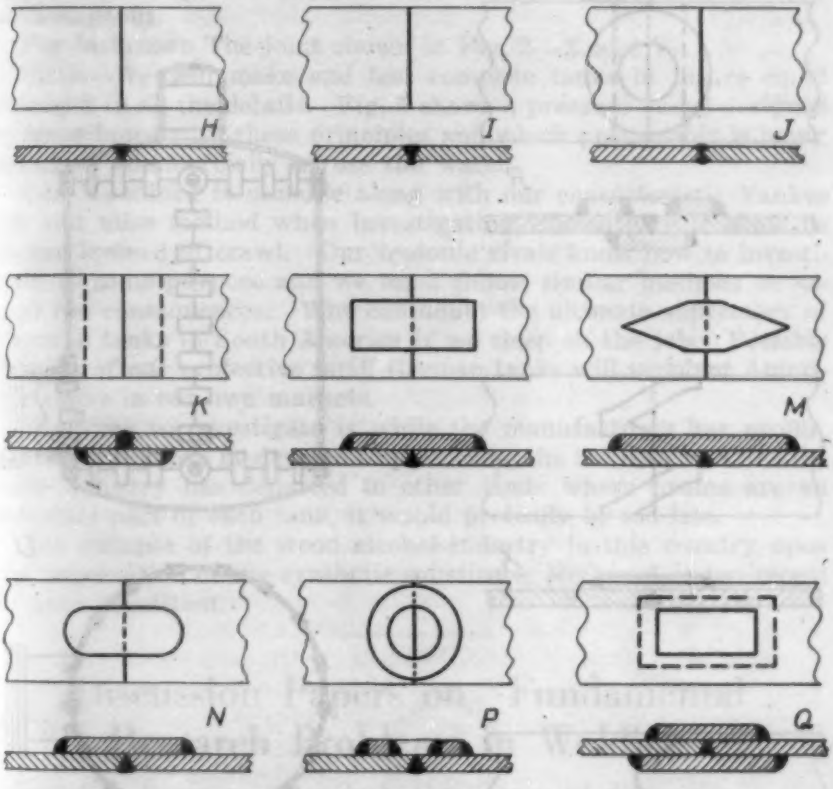
sufficient time and thought to make sure that we will attain our objective?

Second—We will ask a question and plan our investigation so that the answer can be obtained from the results.

A destination is as important for an investigation as for an "Atlantic liner" and a formal statement at the beginning will prevent much misunderstanding, controversy and inefficient work.

Third—We will change one and only one variable while holding all other variables constant. In changing the one variable we will include the entire range from one extreme to the other, going just

as far as it is humanly possible to go. Let me illustrate: If we are investigating the effect of the speed of welding on the strength of the joint, for a tank we should select a uniform plate material and welding rod and have the welds made by the same operator under the same conditions. Making, say, ten tanks, we weld the first at the slowest practicable rate, say, 1 in. per hour, the others



Test Specimens From Joints in Shell Fig. 2

at faster rates until the last tank is welded at the highest practicable rate, say 1 ft. per second.

After determining the bursting pressure of the tanks we plot a curve showing the relation between the rate of welding and the strength from which we find the best rate of welding.

We will pay no heed to experienced welders who insist that many of the rates which we have tried will give poor results. They may or may not be right. We are under the necessity, if we really want the truth, of proving the matter unless, of course, it already has been proved by others. Remember that Taylor discovered his high speed tool steel which revolutionized machine shop prac-

tice by heating his tools to the melting point which anyone could have told him would ruin them. If we cannot approach these problems unhampered by tradition we should leave investigational work to bolder spirits.

Fourth—We will investigate each detail of our tank separately, to find the best design and method of fabrication. We might study

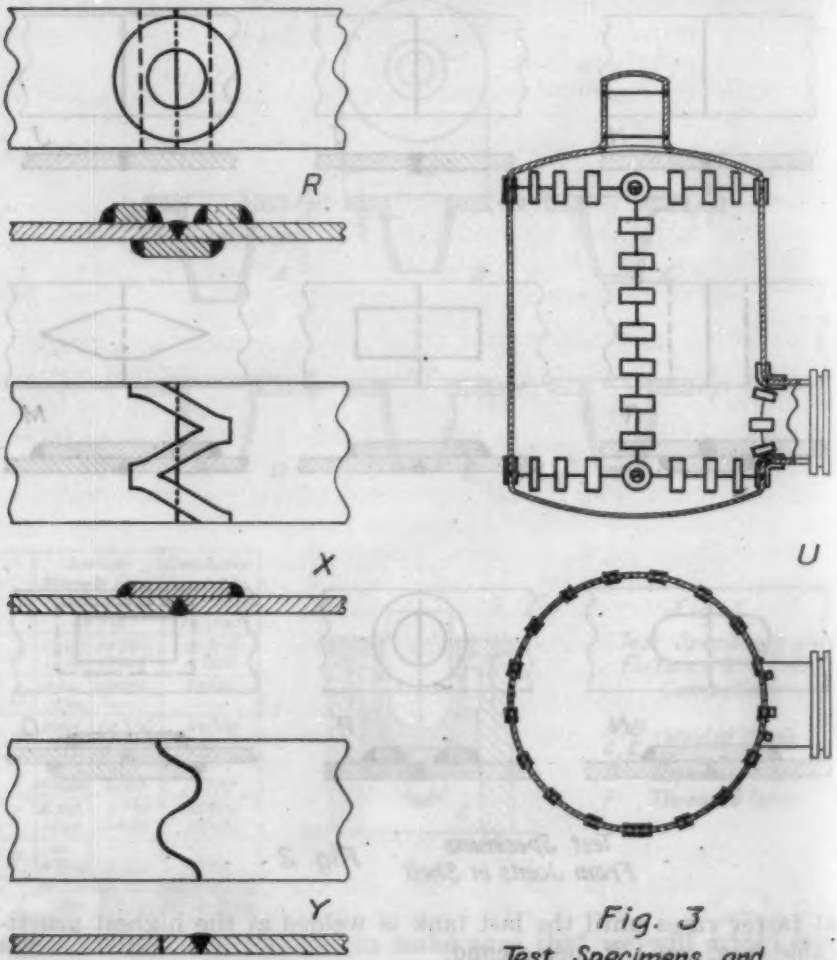


Fig. 3
Test Specimens and Completed Tank

first the seams or joints in the shell, then the opening for pipe connections or manholes.

So far as I know this way of investigating tanks has never been used to any great extent in this country. As an example of the way our cousins across the water go about a job of this kind, look at Figs. 1, 2 and 3. The joints were made in many different ways and the strength of each measured in a testing machine. A num-

ber of the ways of joining the pipe to the tank, shown in Fig. 1, were tried and tested, using the special fixture for gripping the pipe and applying the load.

We will consider every way of fabricating these details which seems to offer any possibility of success. Our tentative program should be broadcast and everyone urged to make suggestions. Perhaps an entirely different joint in the shell will prove to be very advantageous.

For instance: The joint shown in Fig. 2—X and Y.

Fifth—We will make and test complete tanks to insure equal strength in all the details. Fig. 5 shows a pressure vessel designed in accordance with these principles and which presumably is being produced commercially across the water.

Can we afford to stumble along with our characteristic Yankee hit and miss method when investigating efficiently will allow us to run instead of crawl. Our teutonic rivals know how to investigate to some purpose and we must follow similar methods or accept the consequences. Who can doubt the ultimate supremacy of German tanks in South America if we sleep on the job. Possibly in spite of our protective tariff German tanks will supplant American tanks in our own markets.

The time to investigate is while the manufacturer has profits, part of which can be devoted to protecting the industry. After the tank industry has departed to other lands where brains are an essential part of each tank, it would probably be too late.

The collapse of the wood alcohol industry in this country upon the importation of the synthetic substitute, Methanol, is too recent to need repetition.

Discussion Papers on "Fundamental Research Problems in Welding"

Discussion Paper on "Research, the Beacon of Progress in Arc Welding," by H. M. Hobart and W. Spraragen.

CHAIRMAN C. A. ADAMS, Harvard University: The human mind is a matter of ruts and habits of thought. As we go on these ruts become harder and more difficult to surmount, but we find almost universally that the man whose life training has been research, who searches constantly for a more complete and thorough understanding of the phenomena of nature, does not grow old; the ruts aren't formed. Instead of a rut of a habit of thought of doing the thing in a certain way, their rut or habit is to constantly keep searching and the finest men that I know today have grown old in years with the knowledge of the thing that Mr. Hobart speaks of. In other words, they have the scientific habit of mind.

J. W. OWENS, Newport News Shipbuilding and Drydock Com-

pany: The importance of having standard methods of test is one that deserves serious consideration.

One other point that Mr. Hobart mentioned about some one speaking about the extremely ductile weld. I was that party. It wasn't with any spirit of scepticism or doubt about the development. That is what we need. We need welds approaching the base metal as near as we can. On the other hand it is necessary to design the joint so as to throw the stresses out of the weld if possible. We would not want a weld in the design of which the working stresses would be concentrated in the weld, because naturally the bending and fatigue stress would be concentrated at that one point. Therefore, if the weld is much more ductile than the plate, it would be necessary to reinforce it slightly. It would be necessary to throw the working stresses out of the weld, even in more ductile metal.

CHAIRMAN ADAMS: Mr. Hobart made a definite suggestion about a prize for the best paper on some of these research subjects. A prize means money and I was wondering whether it would be possible to raise the money for such a prize.

Another thought occurred to me—the possibility of a scholarship which would be given to competent graduate students in our universities, who could tackle some of these problems under the guidance of first-class scientific men; metallurgists, physicists, as the case may be. Or it is entirely possible in most of our universities to have both metallurgists and physicists, as well as chemists, in contact with the work and assisting and aiding these graduate students. That would be one of the most efficient ways of carrying out some of these ideas as far as cost is concerned. We would then get the whole-hearted and sincere support and assistance from the professors in these various fields in the university where the work was being conducted.

MR. J. C. LINCOLN, Lincoln Electric Company: It seems to me that what we need more than anything else, so far as electric welding is concerned, is more fundamental knowledge of the physics of the arc. I think that anybody who has paid any attention to what goes on in arc welding knows that the fundamental knowledge of that subject was quite limited. There are many questions of what happens in the arc that we are completely and utterly ignorant of and progress is going to depend on research in pure science.

Mr. Alexander spoke of the anode drop and cathode drop in the hydrogen arc. Within the last few months I have had some work which indicates to me that the notion of anode drop and cathode drop is not correct.

MR. L. H. BURKHART, Struthers-Wells Co.: I would like to call attention to one branch of research work that I think ought to be conducted as I intimated at some of the other meetings. There is coming on to the market, and very rapidly, too, these so-called

stainless steels or high chromium irons and users are clamoring for these irons to be made up into vessels which they find are more suitable for their purpose than anything else. The manufacturers find that they cannot make these metals up in the most advantageous way unless they can use welding. So far welding has not proven satisfactory with this class of materials. I believe sooner or later we will find a way of doing it, but the quicker we can find it, the better it will be for the industry.

CHAIRMAN ADAMS: I wish somebody would offer to act as a committee of one to raise five or ten thousand dollars a year for these research fellowships and scholarships.

The situation from the industrial corporation point of view is quite different from what it was a few years ago. There are obviously certain types of research work involving patentable processes which belong to corporations. They have their research laboratories and they are constantly working in them to solve many of these problems. In the case of a few of these laboratories they have men who are fully competent to deal with the pure science side of things. In fact, in one or two cases they have physicists and chemists who are of the A-1 class; men who are equal to any in the country. However, the field is so great and the number of these problems so many that even they with their enormous laboratories and enormous expenditures can't handle half of these things. Moreover, some types of research which are distinctly fundamental —the one mentioned by Mr. Lincoln, for example, as to the physics of the arc—that present no difficulty on the score of patentable processes and research work done in our college laboratories, under the plan that has been suggested, would not bring in any difficulties.

I feel sure from what I know of the attitude of our corporations that insofar as the investigation of these things is concerned, they would be willing to help them along. I would like to see something started and I wonder if we could have an expression of opinion, a very brief one, from the representatives of some of our corporations here, whether they be manufacturers of welding equipment or large users of welding equipment, on the point as to whether or not they think that their corporation would be willing to make a small contribution annually to some such scholarship fund or fellowship fund.

MR. BURKHART: I believe the firm I represent will be perfectly willing to make quite a substantial contribution each year as long as it is necessary to such a fund. I believe that there should be more progress made in welding. I have had quite a change of heart recently along that line. About a year and a half ago we were doing hydrogen welding, but the company then didn't think we ought to broadcast it. We thought we had something that somebody else didn't have, but I guess we didn't. The results we were getting were practically the same as have been described by

others. They see it differently now and I believe they will be perfectly willing to support it in a financial way.

MR. OWENS: I think I can endeavor to get the company I am with to contribute something toward that end.

MR. A. M. CANDY, Westinghouse Elec. & Mfg. Co.: Unfortunately, I didn't get in in time to hear all of Mr. Hobart's paper, but that portion I did hear struck me as being one of the best papers I ever heard outlining what should be done along research lines and the reasons for the research problems. I presume there is an intention to publish Mr. Hobart's paper in the proceedings of the Society and I think that such a paper as that cannot be broadcast too thoroughly throughout the industry. I would rather imagine that the rest of the gentlemen who are in touch with the welding industry and the welding field will probably corroborate my statement when I say that I believe that there is quite a wave, so to speak, of unusual interest within the past year throughout all of the fabricators and tank manufacturers in the metal working industry in welding. I believe the time is coming when it is not going to be very difficult to get outside interests, interests who are not now connected with the Welding Society, to assist in carrying on research programs. Broadcasting Mr. Hobart's paper will help materially with some other organizations who have been connected with the Welding Society but who haven't taken a very great and active part up to the present time.

Discussion — "Some Unsolved Fundamental Gas Welding Problems," by Mr. S. W. Miller.

CHAIRMAN ADAMS: Is there any discussion on this paper, gentlemen? We have, of course, in the gas welding flame a problem that while perhaps not quite so difficult and complicated as the arc, is still a problem. I do not know how perfect the present knowledge of the flame is, but I should think there might be some room for a study of the physics of the welding flame, the same way that you have been discussing the physics of the arc.

I am going to submit these papers to the Executive Committee of the Bureau for consideration, with the view to action, and if any of you have any suggestions apart from general discussion of the papers, as to the desirability of certain procedure, in order to get something moving and actually get results, I should be very glad to receive them.

Discussion — "Welding in the Structural Field," by Mr. J. H. Edwards, American Bridge Co.

CHAIRMAN ADAMS: Gentlemen, I am sure you all agree with me in expressing my highest appreciation of this review of the structural steel situation and of the level-headed and sane discussion of these various points.

MR. W. A. SLACK, Torchweld Equipment Co.: Mr. Edwards' paper is a very interesting paper on something that is coming and they want the proper information.

Manufacturers of apparatus have their troubles with the users to give them the proper information. There isn't a plant that one goes into that hasn't got the best welder in the country and nobody can go into that plant and give them the proper information. In this new industry that we are developing some people are going faster than they should and there isn't a plant that does welding that hasn't got some welder who tries to do a job that he should not do. He gets by with that one job and the next one he makes a failure of. That is what we want to eliminate if we possibly can.

Take the guess work out of welding, whether it is electric, resistance, butt or gas welding, and have the master mechanic, the general foreman or the plant superintendent know what he is doing when he is instructing his men to do this job. I think the different manufacturers are trying to cooperate with the users in this respect. There has been too much guess work in welding and in the last two years the guess work has been eliminated to a certain extent. If each individual welder would not try to do jobs that he shouldn't do, we would have very few failures in welding.

MR. E. H. EWERTZ, Bethlehem Shipbuilding Corporation: It strikes me as I have been sitting here listening to you gentlemen talking that we have the same condition confronting us today as we have had in the Welding Society since the time I have been connected with it and that is we have three groups of people and conditions. We have a group of manufacturers who have problems connected with the product that they are trying to produce. They have failures and they would like to eliminate those failures purely from the standpoint of increasing their sales. The American Welding Society is trying to help that group insofar as the group is willing to help the Society.

Then we have the group of new activities, an extension to the welding art, where the doubtful and skeptical mind has to be supplied with fundamental facts, not facts given by either the sales force or even by the individual manufacturer's research department, but rather given by an unbiased and nationally known organization which can standardize and produce results which will be acceptable to the new field such as Mr. Edwards has spoken of. I don't blame the structural engineer for being skeptical. If you listen to the whispers that you hear from the inside you will soon find that the contradiction by the different manufacturers of equipment as to what can or cannot be done by one or another leaves very much of a picture in your mind that there is no sure way of doing anything. And that again is the reason why we have to get away from all the activities connected with individual manufacturers of equipment. We appreciate that they do a wonderful

work. We have heard some wonderful papers in connection with the work they have done or contemplate doing. But until they submit them to a body of national reputation, unbiased by any interest in manufacture of any kind, it will not be accepted by the structural engineer and by many others.

Then we have a third group who research in connection with the fundamentals pertaining to the art of welding. That is, as has been said, can only be understood by people who are highly trained to reason out why. Most of us who are manufacturers don't like to be bothered with the why. We like to just jump over that and go to work and do something. It is a very difficult thing to find a man who has the patience to take what seems like a perfectly good result and then break it down and ask why he got it. Yet that is just exactly what we need and so I sincerely hope that the money will be found available whereby we can find out just what the gas flame is, fundamentally, right down to the bottom facts, as well as the arc.

MR. CANDY: It strikes me that Mr. Edwards' paper is really a keystone paper. I only wish that two or three hundred representatives of the American Institute of Steel Construction could have had the privilege of hearing what Mr. Edwards had to say. The thing that struck me was the very open-minded attitude that Mr. Edwards takes toward the use or the adoption of welded joints in steel construction. It has been my experience in the past that when you approach a fabricator and propose the use of welded joints in steel construction or in other metal working industries, they expect you to be able to step into their organization and tell them how to make all the joints; how to make all the jigs and fixtures in shops and give them detailed methods of doing the field erection and the whole thing, so to speak. Mr. Edwards and his company are not asking this at all. They realize their responsibility. All they are asking is for us to set before them certain facts and figures on the unit stresses which welded joints can be counted upon to sustain and to give them to a certain limited extent the best forms of welded joints and they will work out the problems of assembling the material and making the joints and determining the ultimate cost.

It seems to me that is the only way this problem can be worked out. Those of us who are interested in pushing welding are not in a position to carry out that whole program. We can only give them a certain small portion of it to start on. They have got to carry it through to conclusion. It seems to me that if some of the other steel fabricators would take that attitude we would progress more rapidly.

Mr. Edwards brought up the question of going into the higher tensile strength steels involving higher carbon content. It is true that at the present time we have more or less generally agreed that the lower carbon content steels gives us a more fertile field for

the use of welding. In the light of certain experiments that have been carried on and in the developments that have been brought about so far I honestly believe that we will be able to satisfactorily weld the higher tensile strength steels and steels containing greater carbon content.

CHAIRMAN ADAMS: I think one conclusion that we must draw from Mr. Edwards very fine presentation is that we have a job ahead of us. As all of you know we have been planning for the organization of a comprehensive research in this field to the end of supplying exactly the information which Mr. Edwards has asked for. We must draw into our councils other structural engineers like Mr. Edwards and make sure before we lay out a program that it is going to provide as far as possible the information desired.

Discussion, "How To Investigate Welded Tanks," by Prof. H. L. Whittemore.

CHAIRMAN ADAMS: I would like to comment on the refreshing atmosphere of Dr. Whittemore's remarks. Nobody did anything in this world that was worth while that some one didn't say it couldn't be done. It often happens that new designs of structures appear to be, in the minds of those who have preconceived ideas and know all about the customary methods, very complicated and very expensive. There is almost always some method of producing these results at small expense, if there is ingenuity enough back of it, or they really want to do it. It is the inventive type of mind that always does what most people think can't be done.

MR. A. G. PACK, Chief Inspector Locomotives, U. S. Government: Whenever a man begins to devote too much of his time to telling us why we can't do things, he is wasting a whole lot of time. No man knows what can be done unless he tries it. No man ever accomplishes anything until he starts out with the determination of accomplishing it. When we get into an old rut and then get out of it we wonder why we stayed there so long. When we progress so far that we can't progress further we have about lost our usefulness.

Now, speaking of scalloped seams that Prof. Whittemore suggests, I know of one or two railroads that are experimenting with scalloped seam instead of a straight seam for the past two years in locomotive firebox work. They claim to be getting most excellent results from it. And the failure when it does come is very much less than with a straight seam, because the direction of tear is in so many different directions. There is no question in my mind but that this sawtooth seam here is stronger and more substantial than a straight seam. What we are trying to find is something that will give the best results.

I want to say to you that I have listened to the arguments here for the past three days very intently and with a great deal of interest and I am in hearty sympathy with the work in which you

are engaged and whenever you can remove that chamber of horrors that I have in my office I will be with you 100 per cent.

MR. W. SPRAGUE, Division of Engineering, National Research Council: Dr. Feuchsel of Germany made some of these tests that have been talked about and I would like to hear from him.

DR. MAX FUECHSEL, Chairman of Welding Committee, German V. D. I.: In relation to the proposals of Mr. Hohn reported by Dr. Whittemore, I wish to state they are good ones and very interesting, but this is not the common opinion of German welders. By welding straps on the seam there are different thicknesses of the material of construction and therefore a difference of stresses in the different parts of the construction. This is not a good condition. This test is used as an investigation test but not in common use in workshops, although I believe the test is always a good one if done by an expert man. Our regular test for welded specimens is the cold bend test.

DR. H. L. WHITTEMORE, Bureau of Standards: I think that the Germans have carried the stress analysis much further than we have in this country. Strain gauges have been known for twenty years. There is no trouble about using them, but very few people do use them.

MR. CANDY: It might be interesting to note that up in the New England States there is a small shop which has been making boilers for a number of years and while they haven't adopted this snake joint for the main joint, they have always laid out their butt strap with the edges of the butt strap cut in this form and welded along those two seams with the main joint straight, such as was intended in one of the figures shown by Prof. Whittemore. As far as I know they never had any failures with any of their boilers and always relied upon their construction to give them additional strength in the joint.

MR. LINCOLN: I would like to ask the gentleman from Germany who has just spoken, how the welding is done over in Germany.

DR. FEUCHSEL: Bar wire metallic arc.

MR. A. G. OEHLER, Simmons-Boardman Pub. Co.: In defense of my profession and in connection with publicity as it relates to research work, I would just like to make one remark which really should apply to the discussion of Mr. Edwards' paper and that is simply this: We of the technical press are not inclined to accept anything as genuine which comes out of the medium's cabinet unless we know what is going on inside. I think that practically all of the doubt in the mind of any prospective user of a welding process arises from either one cause or another. One may be ignorance and the other one is engendered usually by the exploitation of one process at the expense of another. I am particularly gratified at the progress made in this meeting and I don't think anything will ever be injured, whether it pertains to practice or research work, by the light of publicity if that process or those facts are worthy.

MR. H. S. SMITH, Prest-O-Lite Co.: I would like to see a joint meeting of the Bureau of Welding with the Mechanical Engineers. If we had a gathering of men at a meeting with the Mechanical Engineers like we have here today, we would give some status to the Society. This creates a far better impression than an ordinary meeting of the Welding Society. You have men here today who know what they are talking about. After hearing Mr. Edwards' remarks today, don't you think such a meeting with the Civil Engineers to discuss structural work would be a very fine thing, too?

CHAIRMAN ADAMS: It would be entirely possible, I think Mr. Smith and gentlemen, to have such a joint meeting at the times of the annual meetings of those two societies.

MR. SPRAGEN: We will try to have joint meetings with their research committees.

MR. PACK: When we come in contact in our daily life with one another the horns don't stick out on the other fellow half so far. I am not a technical man, but some of the most beautiful things have been developed in the laboratory and they must be developed there in the first place, but generally we have to judge from the practical results. It doesn't make any difference how well a structure may be designed, if it falls down, why it isn't any good. All of those things should be given consideration in these discussions, if I may be pardoned for making that remark. I appreciate extremely the privilege of being with you on this occasion and appreciate having been invited here and I think I have profited materially from what I heard. I hope that what I may have said here will be looked on in a charitable way.

CHAIRMAN ADAMS: Not only in a charitable way, Mr. Pack, but as very helpful. We appreciate it highly and hope you will come to all our meetings.

Welded Crane Runway*

BY A. F. DAVIS†

The process of electric arc welding has again made an important stride forward in its march to general acceptance as the logical means of joining steel members in the structural field.

The Morgan Engineering Co. of Alliance, Ohio, added another accomplishment to its credit in the building of a great industrial crane runway without the use of rivets. The importance of this new accomplishment may be better understood when it is known that the welded runway and supports constituted one of the major portions of a thirty-five thousand dollar installation made by Morgan for the Coplay Cement Manufacturing Co. in its plant at Coplay, Pa. In addition to this the contract called for the supply-

*Presented at New York Section Meeting, A. W. S., March, 1926.

†Vice-president, Lincoln Electric Co.

ing of a ten-ton crane of the bucket handling type, to be operated over the runway.

Involved in the welded job, there are approximately sixty-five tons of steel for the supporting frames and crane girders, which provide a runway of 245 ft. Welding replaced riveting on all of the shop-made connections. While the fact that the sixteen supporting frames and the fourteen girders each of 35 ft. length for the Coplay crane runway were all fabricated by welding is signifi-

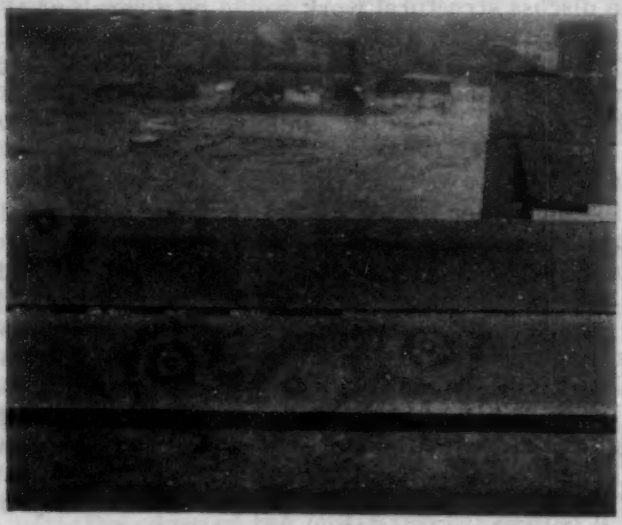


Fig. 1. Welding back of angles to edge of web plate

cant in itself, yet the greatest importance to be attached to this job comes from the extended possibilities it opens up for the use of this method of joining steel on a large scale and in a great diversity of fields.

For more than half a century Morgan has been known the world over as a builder of cranes and crane runways. In its own shop, this firm has been constantly using electric arc welding on a diversity of jobs, so that it was not surprising that when the need came for a new crane runway electric arc welding was used for the shop work.

There were 1800 linear feet of continuous bead on the fourteen girders and 2035 ft. in intermittent welds on these same steel members. On the supporting "A" frames there were 596 ft. of continuous bead and 403 ft. of intermittent beading.

The fourteen plate girders make a runway of seven bays, with a span of the crane supported by this runway of 100 ft., center to center of rails. The height of the twelve "A" frames supporting the girders is 21 ft. 11 in., while four others run to a greater height in order to make a roof over a portion of the runway.

The load on the runway from each of the 4 wheels supporting the crane is 55,300 lb., plus 25 per cent thereof for impact.

Although this heavy duty runway was the first to have been shop welded all of the way through, was submitted to unusual tests and designed for the greatest possible strength, reports of the company show that a saving of 15 per cent of shop labor costs were effected over the expense which would have been involved had riveting been used. The time required for welding of the girders totaled 1050 hours, and for the twelve supporting "A" frames, 320 hours.

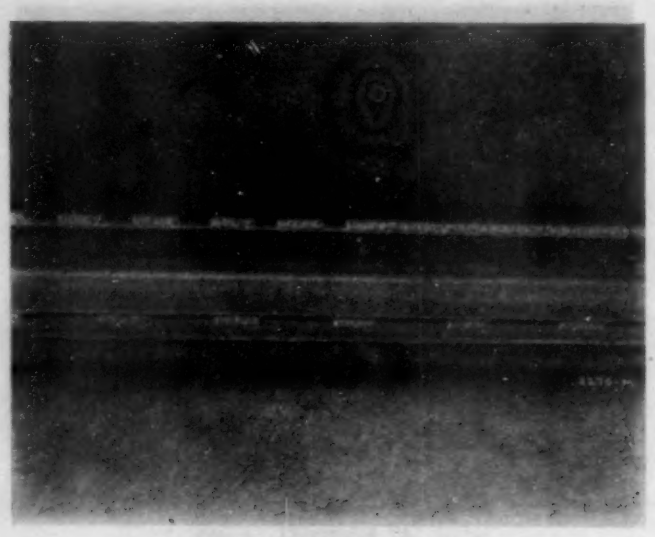


Fig. 2. Welding toe of angle and web plate

The crane girders were made up of a web plate 42 in. wide by ½ in. thick, with two 6 x 4 x ⅝ in. top flange angles covered by a 15 in. stiffener channel. A bottom flange of two 6 x 6 x 9/16 in. angles was provided. Backs of the flange angles were set ⅜ in. from the edge of the web plate, and each angle then welded to the edge of the web plate. On this work a third bead was then laid joining the two beads connecting the angles to the edge of the web plate. Flange angles were also welded to the web plate along the toe of the leg against the web plate. All of this welding was continuous for a distance of approximately 4 ft. from each end of the girder. On the balance of the distance to the end of the girder intermittent welds were used and were spaced 2½ in. alternate between the backs and the toes of the angles. On the average these welds were about 2½ in. long. In previous exhaustive tests the length and size of bead required to replace different size rivets in different thickness of plate were determined.

Fig. 1 shows the manner of welding between the back of the angles and the edge of the web plate.

Fig. 2 illustrates the welds that were also made between the toe of the angle and the web plate, and the method of attaching the

15 in. stiffener channel to the top flange angle by intermittent welds 2½ in. long, space about 8 in. centers.

Fig. 3 shows the manner in which flat bars were used for the stiffeners. These bars were edge welded to the web and the top and bottom flange angles. A flat bar was welded to the web which holds the bracket for a footwalk, which footwalk extends the entire length of the runway.

Fig. 3 also shows the attractive make-up of a completed and all

Fig. 3. Completed girder

welded 35 ft. girder as it was arranged for shipment to the Coplay plant. As it stood this girder alone had a total weight of approximately 6800 lb.

In building the great supporting "A" frames the company simply replaced the rivets that would have been used in the past with welds of various lengths according to the requirements set up by the engineers on the job. These frames, which support the runway girders, were set on top of concrete piers at the Coplay plant, in the same manner as would have been employed on any average job of corresponding size.

Fig. 4 shows the appearance of the "A" frame completed after all welding has been done and the support ready to ship from the fabricating shop for installation in the cement plant.

Of the total of 16 frames, such as that illustrated, all but four were of the standard length for this job, 21 ft. 11 in., each having an approximate weight of 2500 lb. The remaining four, identical save for the fact that they had extensions to carry a roof over one portion of the runway, each entirely electrically welded, weighed approximately 3600 lb. apiece. Further details are shown in Fig. 5.

It is important to note that in addition to the 15 per cent saving

effected on shop labor on this runway job through the use of welding, in place of the older riveting methods, an additional saving was made possible in the quantity of material required. On the "A" frames it was possible to somewhat reduce the quantity of steel required over that which would have been involved on a riveted job; this came about in the matter of detail gusset plates, which would have been necessary had the "A" frames been riveted.

Welding resulted in materially decreasing the amount of pre-

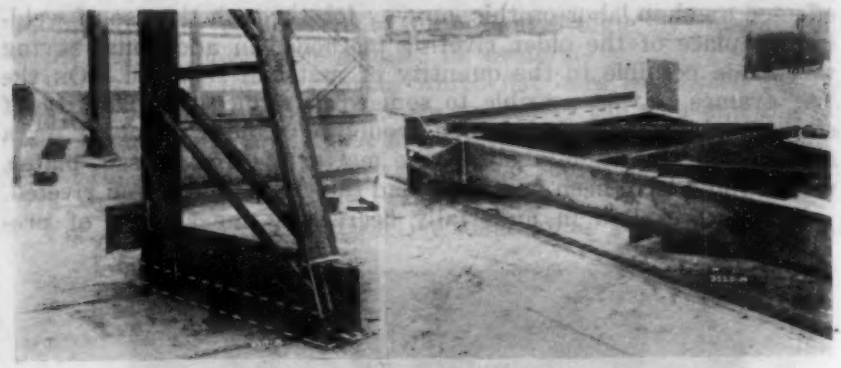
Fig. 4. Completed "A" frame

liminary drawings involved and in reducing the time devoted to engineering work prior to the actual start of construction on the runway. In the course of fabricating the girders and frames, it was not necessary to consume any time in the punching or making of holes in the steel members, such as would have been required had the plates, angles and beams been joined by rivets driven through them. In other words, the use of electric arc welding tended to put the job on a simplified basis.

More important even than this phase of the job was the fact that through the use of welding it was possible to get uniformly good connections.

As has been demonstrated time and time again, through the application of electric arc welding in the joining of steel members, tests conducted on the crane runway showed the welded joints to be at least equal in strength to the steel which they served to join. When compared with the riveted joint, which at best is said to be but from 65 to 75 per cent, it becomes obvious that the welded connection is by far the more desirable.

The welded joints of the runway were put to the severest possible tests, and in every case stood up without signs of giving



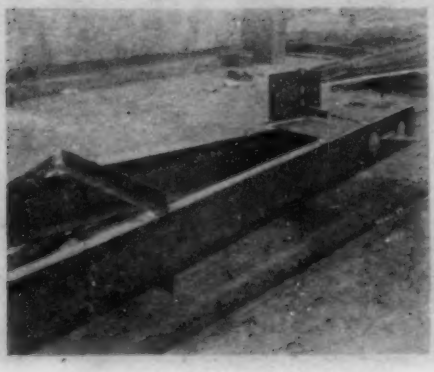


Fig. 5. Details of "A" frame

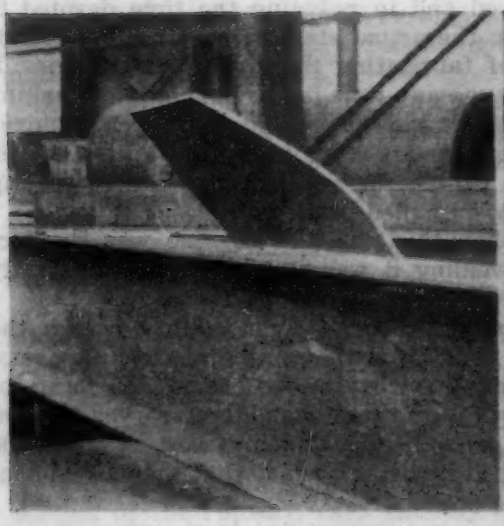


Fig. 6 Fig. 7

Results of impact test on welded plate to I beam

away. One of the tests was conducted in connection with a plate 13 x ⅜ x 10 in., which was edge welded to the flange of an I-beam. The 13 in. edge of the plate was welded to the I-beam and the 10 in. side was set vertical. The plate was hit a total of sixty blows with a 12 lb. sledge and bent into approximately the shape shown in Fig. 6. This treatment did not affect the weld in the slightest. A steel ram weighing 587 lb. hung from an overhead crane. This was used to strike the plate a total of forty-six blows, with four men behind the ram, endeavoring to break the welded plate from the I-beam. The blows were all directed as close to the bottom of the plate and the weld as possible. After all of this very severe abuse there was not a single sign of cracking in the weld.

Another test to which this type of welding used upon the runway was put is illustrated in Fig. 7. A plate 8 x ⅜ x 9 in. was welded to the web of an I-beam, the 9 in. dimension being vertical. The plate was then bent by hitting it about sixty blows with a 12 lb. sledge. The result upon the plate is shown by the bent position which it represents in the picture. There was absolutely no evidence of a break in the weld.

As has been the case in numerous other instances on record, the application of welding on the runway brought about a material saving in shop labor costs; involved somewhat of a saving of steel materials, and helped simplify this class of work.

Discussion of Papers

The Meeting and Papers Committee invites written discussion of any paper printed in the Journal. These discussions will be printed in an early issue of the Journal!

Design of Oxwelded Equipment*

E. E. THUM†

It should not require much argument to convince one that it would be lazy engineering to take a design developed by experience for one type of construction and expect the best results when applied to a radically different type. For example, where western railroads pass through heavily timbered country, wooden trusses are frequently used for spanning small gullies. Wooden truss design is characteristic of the nature of the material used—it is no slavish copy of the steel trusses used elsewhere on the same lines. Again, reinforced concrete buildings are not made from designs intended for steel skeletons; a knowledge of stress distribution in beams, slabs and columns will be used to distribute properly the steel for tension and the concrete for compression. In the same manner, an engineer would not be satisfied to take a design for a riveted truss and merely note on the drawing: "Substitute welding for riveting" and expect to get satisfaction, or the greatest economies.

Definite proof of this general position (if proof be needed) is now available.

A modern lime-burning plant was placed in operation late in 1923. It contained three huge kilns, each 125 ft. long and 8 ft. in diameter. Two were riveted and the third oxy-acetylene welded.

Riveted kilns of this size have usually been made of $\frac{5}{8}$ in. plate, with butt strap joints; double riveted on longitudinal seams and triple riveted on circumferential seams, as indicated in Fig. 1. A theoretical analysis of the stresses of such a kiln when in operation under full load indicates that the greatest forces existing in the steel plate are about 4700 lb. per sq. in., which is only 30 per cent of the safe design load for structural steel in buildings. Undoubtedly the metal in such a design is not working to anywhere near its capacity, but since experience indicates that riveted kilns should be made of $\frac{5}{8}$ in. plate, the welded kiln was also made of the same thickness. The joint, however, is extremely simple. Contrast Fig. 2 to Fig. 1.

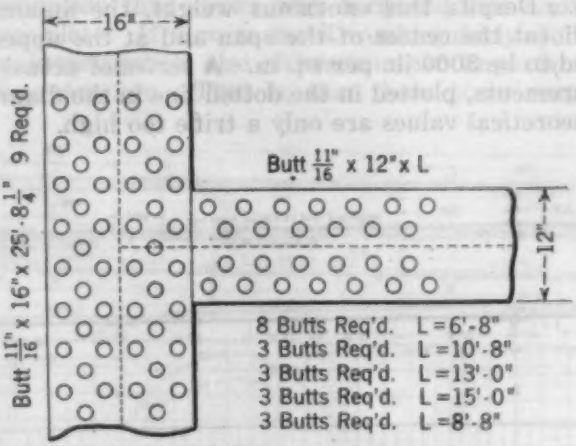
After two years' successful operation, and in order to determine if possible the reason for such a large excess of metal required in the shell, Mr. T. W. Green of our company made a series of determinations of the stresses existing in the steel plates. This investigation was made by means of an extensometer, a precise gage for measuring small changes of length in metal as the loading is applied or relieved.

Fig. 3 shows a diagram of the results of tests on the oxy-acetylene welded kiln running empty. (The vertical scale of the sketch has been much magnified, so the kiln appears to be several

*Presented at Annual Meeting, A. W. S., April, 1926.

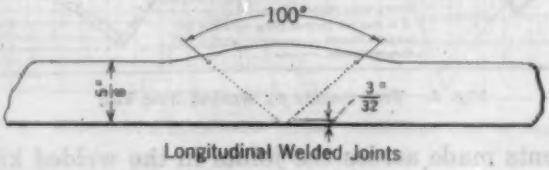
†Manager, Publicity Dept., Linde Air Products Co.

times as large in diameter in comparison to its length as it actually is.) The horizontal straight line 0-0 represents no stress, and the distance from this line vertically to the curved line represents the amount of stress in the shell at the corresponding distance from the end. It will at once be recognized that the kiln acts as


16"
Butt 11/16" x 16" x 25'-8 1/4" 9 Req'd.
Butt 11/16" x 12" x L
12"
8 Butts Req'd. L=6'-8"
3 Butts Req'd. L=10'-8"
3 Butts Req'd. L=13'-0"
3 Butts Req'd. L=15'-0"
3 Butts Req'd. L=8'-8"

Detail of Butt Riveting Replaced by Oxwelded Construction

Fig. 1. Double and triple riveted seams for lime kiln



Longitudinal Welded Joints

Girth Welded Joints

Fig. 2. Welded seam for lime kiln

a long beam, overhanging its two supports. At the very ends the bending stress will be zero; the stress in the steel gradually increases to a maximum at the supports. From the supports toward the center, the compressive stress (in the bottom, for instance) quickly decreases and reverses its direction, and at the center of the span increases to a maximum tension. Stresses in the top of the shell, of course, are exactly opposite, tension where

the diagram shows compression, and vice versa. As the kiln rotates, these stresses continually change; what was once at the top of the shell soon becomes the very bottom, and then back again, reversing the loading at every rotation. Such continually changing load is most severe service to withstand.

It was estimated that the shell plus the lining, empty, weighs 360,000 lb. Despite this enormous weight, the maximum stress in the shell (at the center of the span and at the upper support) is computed to be 3000 lb. per sq. in. A series of actual extensometer measurements, plotted in the dotted line in the diagram, shows that the theoretical values are only a trifle too high.

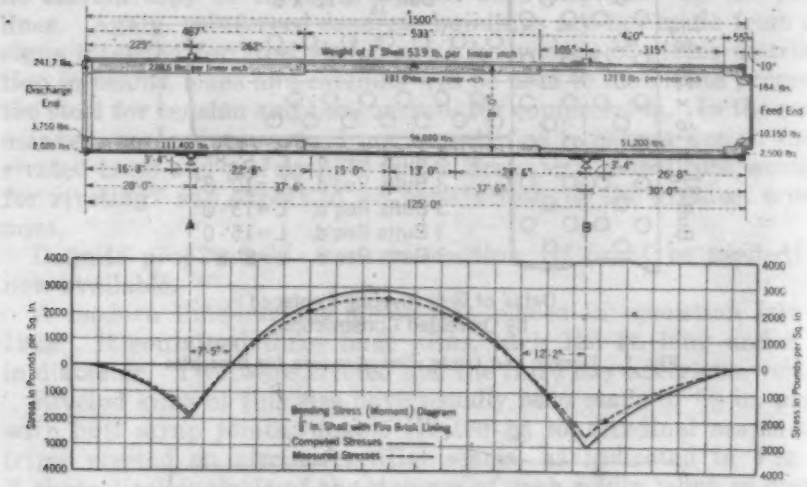


Fig. 3. Test results on welded lime kiln

Measurements made across the joints in the welded kiln showed no undue movement. In other words, the oxy-acetylene welded joint acted as a homogeneous portion of the shell. Similar measurements across triple-riveted butt straps in the riveted kilns, however, showed movements from 2 to 2 1/3 times the amount existing in the plates immediately alongside. This excess movement is undoubtedly due to a slipping of the sheets, in and out, in and out, every time the kiln rolls over. It cannot be laid to poor and loose riveting; as the work was done in a modern shop with hydraulic machinery, under the closest supervision and inspection. It is undoubtedly an inherent action in a riveted joint, observed in hundreds of other structures, where unequal distribution of alternate loading on the rivets causes progressive loosening of the joints. Users of riveted kilns expect to shut down before many years, rip out the lining, and redrive a lot of loose rivets. This need never be expected in a welded construction.

The maximum possible loading is shown in Fig. 4, when a heavy collar of material has sintered against the shell near the hot

end. Even under these conditions the maximum stress in a welded shell is about 4700 lb. per sq. in. However, after only 2½ years of operation, the riveted joints would show movements under the same loading equivalent to a unit stress of 2 1/3 times as big, or 11,000 lb. This is approaching much closer the safe limit for a steel structure.

The investigation thus shows why a riveted kiln must be made of such heavy plate. If it were not it would quickly work itself to pieces. The investigation also shows another important fact not known three years ago. That is, that there is no reason why a

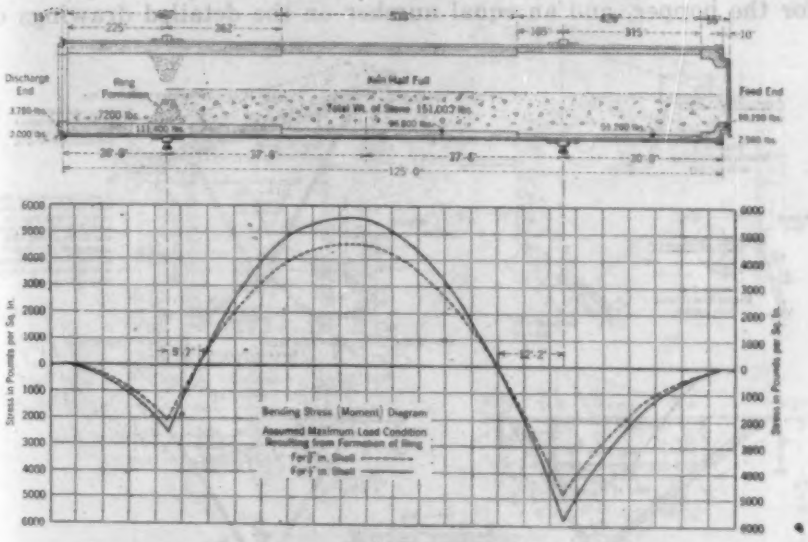

Discharge End
Ring Formation
Feed End
Bending Stress (Moment) Diagram
Assumed Maximum Load Condition Resulting from Formation of Ring
For 1" in. Shell
For ½" in. Shell
Stress in Pounds per Sq. in.

Fig. 4. Illustrating maximum stress conditions due to loading

welded shell should be as thick as a riveted shell. Large savings thus are possible.

For instance, the dotted line in Fig. 4 indicates that the maximum possible stress in a welded kiln of this size made of ½ inch plate would be only 5600 lb. per square inch (certainly a modest value). For this loading, seldom if ever reached, the factor of safety is 6.4, based on the elastic limit, or 8, based on the ultimate strength after allowing a joint efficiency of 80 per cent. These factors will appeal to designers as extremely conservative. Maximum shearing stresses do not exceed 1100 lb. per sq. in.; temperatures never run much more than 400 deg. F., and dynamic stresses are negligible.

It is obvious that by reducing the shell thickness from ⅝ to ½ inch, a very marked saving can be effected, thus reducing the cost far below the riveted construction. In addition to saving 8 tons of steel, there would be a material saving in bending, handling, freight and erection. Furthermore, the actual cost of welding

would be at least 1/3 less, as the cost decreases very rapidly with decrease in plate thickness.

Savings in Drawing Room Expense

One item in welded design which is seldom appreciated is the saving in drawing room expense—in the time of draftsmen, tracers and checkers. This is immediately apparent in a comparison of Figs. 5 and 6.

Figure 5 shows a skew hopper, one of a large number of similar special details for a dust collecting system. The riveted design involves accurate location and dimensioning of about 100 open holes for the hopper, and an equal number on the detailed drawings of

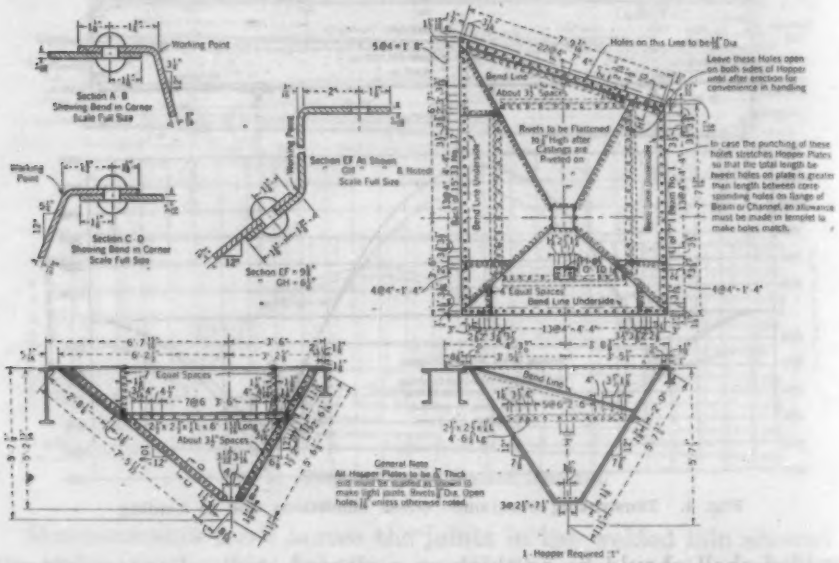

Working Point
Section A B
Showing Bend in Corner
Scale Full Size
Section C D
Showing Bend in Corner
Scale Full Size
Section EF As Shown
GH = 6
Scale Full Size
Section EF = 9
GH = 6
Holes on this Line to be 1" Dia.
Leave these Holes open on both sides of Hopper until after erection for convenience in handling
Bend Line
About 3" Spaces
Rivets to be Flattened to 1" High after Castings are Riveted on
Bend Line Underside
Equal Spaces
Bend Line Underside
404'-1' 4"
404'-1' 4"
Equal Spaces
About 3" Spaces
Bend Line
General Note
All Hopper Plates to be 1/4" Thick
Holes 1" unless otherwise noted.
1 Hopper Required

Fig. 5. Riveted skew hopper

the supporting beams. One such drawing requires a total of about four days to compute, draw, trace and check.

Contrast the simplicity of Fig. 6, the same hopper designed for welding. Joints would probably be at the corners; the top edge will also be welded to the supporting beam flange. It is only necessary to develop each plate, show its true dimensions, locate any necessary bend lines, and the drawing is done. Less than half the time is required in the drawing room.

This advantage is multiplied when the work gets into the shop. Fig. 6, the welded design, merely requires reproduction to scale on the metal. If sheets are too small, corners are welded on where necessary. Reentrant angles are easily cut with the blowpipe. The riveted design, however, requires considerable more "drawing" by a layout man of high ability. He must develop the true size of every sheet he cuts, make proper allowance for all the flanging, make

careful note of all working points, and locate every rivet accurately on two (sometimes three) different pieces of metal. These various shop allowances are often treated as private property and the draftsman does not have the information necessary to draw templates for riveted work. In welded design, however, it is advantageous to indicate the cuts and bends on the drawing so as to have minimum waste and minimum welding, at the same time conforming to the available sizes of sheets and the possibilities of the bending equipment.

More needless expense, both in drawing room and foundry, can be saved by oxy-acetylene welding the outlet gates to the bottom

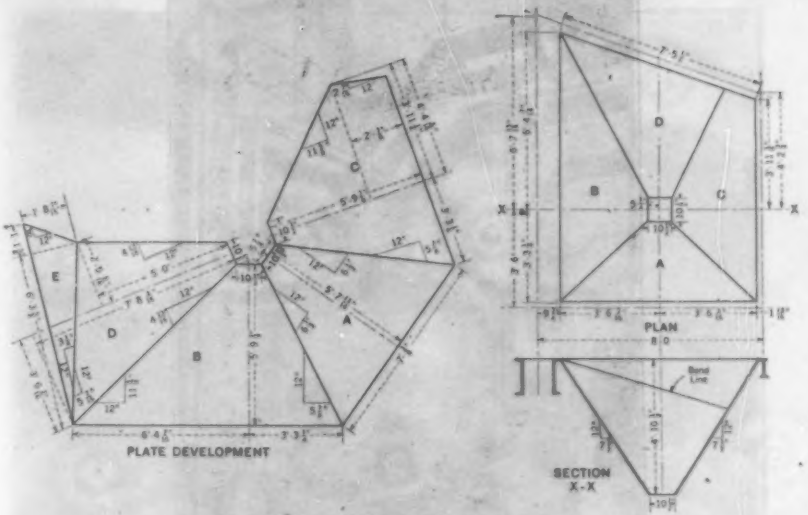


Fig. 6. Welded skew hopper

of each hopper. This particular dust collecting system required at least fifty different drawings for these castings, to accommodate the different slopes of the hopper sides. Each drawing required an individual pattern to be made. At least three out of every four of these specials could have been eliminated by merely butt welding the cast iron gate housing to the end of the steel hopper, using bronze welding rod.

Incidental advantages, beyond the cost of drawings, are also worthy of attention. The load supported by these hoppers (a few feet of flue dust) is so moderate that the minimum plate thickness required for rigidity during handling and for corrosion allowances (3/16-in.) was selected for the riveted design. However, a saving of all lap joints is effected by welded corner seams; this amounts to 158 lb. on a hopper weighing 880 lb., or approximately 18 per cent of the steel.

Finally, a pronounced operating advantage would accrue. The dust collecting system under discussion was designed to produce a fairly strong draft. Unfortunately, there were so many small

holes at the corners of hopper connections, and so many tiny leaks along the single riveted seams, that the operation of the entire plant was seriously hindered for months—in fact, until a great amount of calking, filling and patching had been done.

We may therefore recount the savings from an oxy-acetylene hopper system as follows:

Saves more than half the draftsman's time on details.

Saves 90 per cent the time in the layout shop.

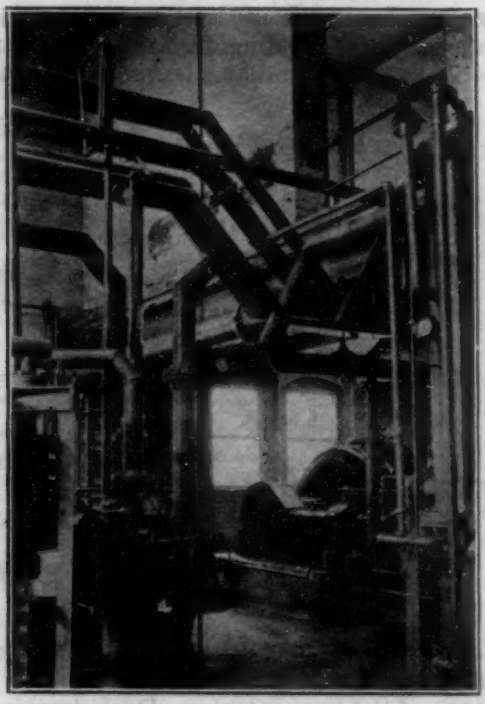


Fig. 7. Complicated piping layout successfully fabricated by welding

Saves three-quarters of the pattern expense on gates.

Saves 18 per cent of the steel required.

Eliminates operating troubles due to draft leakage.

Certainly this is an imposing array of economies.

Pipe Systems

Very large savings in material can be made when pipe systems are designed for oxy-acetylene welded joints. Incidental savings of large amount can also be made in labor charges, both in the shop and in erection, if proper attention is given the matter when it is on the designer's desk.

Since the standard pipe thread for screwed fittings 3 to 10 inches in diameter is about one-tenth of an inch deep, it follows that the

wall thickness of any such pipe, (whether standard weight, extra or double extra strong) could be reduced one-tenth of an inch were the joints to be welded. That extra metal is added to the entire length of the pipe so that a few inches of it at the ends can be cut away again for threads. This one-tenth of an inch amounts to a surprisingly large amount of metal—for instance, it weighs a ton for every 300 feet of 6-inch pipe!

This does not mean, of course, that wall thicknesses of pipe can be figured exactly and pipe of this material then purchased. It does mean, however, that in many power installations standard

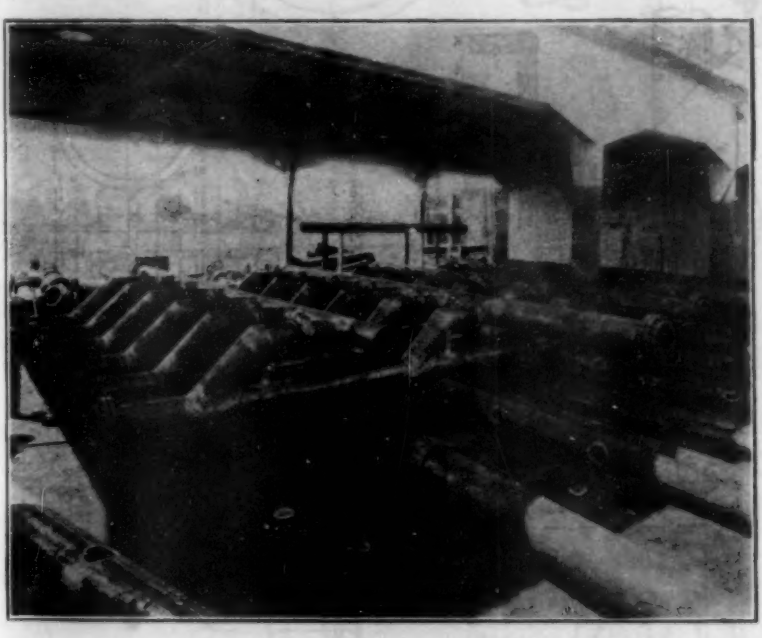


Fig. 8. Special angles made by oxy-acetylene welding

weight pipe (unthreaded for welding) would be as suitable for the purpose intended as extra strong pipe for screwed flanges and fittings. It also means that for long oil and gas transit lines, pipe makers will furnish "line pipe" of considerably thinner wall and longer lengths, unthreaded and beveled for welding, than the corresponding sizes of pipe for screw couplings.

All these make for lower first cost of materials without jeopardizing the utility of the line in the least.

It has been found very desirable, from the standpoint of overall economy, to spend some money on the design and layout of intricate pipe systems for power or pumping plants and industrial works, even in pipe of moderate size. In the past, only enough information would be given on the drawings to indicate the size and weight of the pipe to be used, and its general course from one

point to another. The pipe fitter on the job would make the necessary measurements from point to point, cutting and threading the individual lengths to fit, one after another, very laboriously with bench tools. Even if there were no delays for missing or unordered fittings, this method is very costly in time and labor.

Such layouts as shown in Fig. 7 (and even for simpler ones) can profitably be developed and dimensioned on the drawing board and constructed entirely in the welding shop. The various portions, in convenient lengths for shipping and handling, are then erected one by one from inlet to outlet, in a small fraction of the time previ-

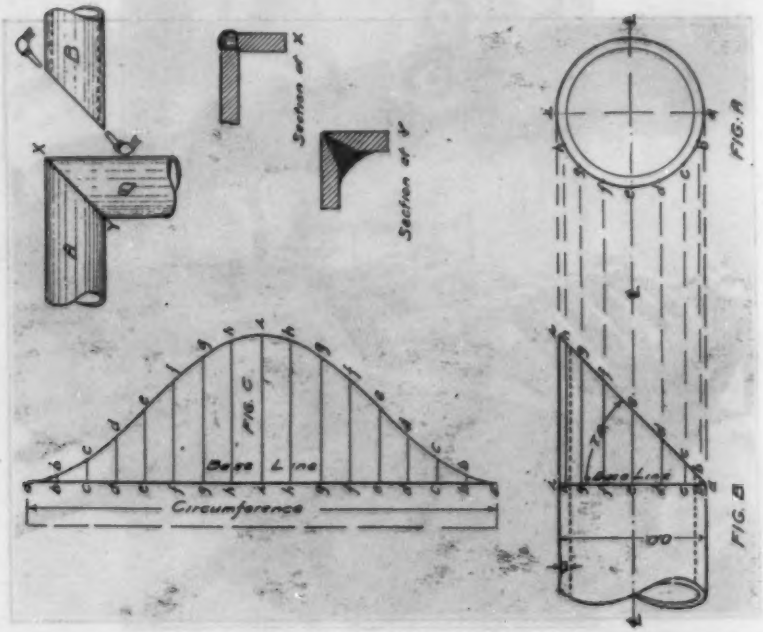


Fig. 9. Template for a "stove-pipe angle"

ously required. In such construction, flanges are only necessary where pipes must be dismounted frequently, where valves are inserted, or when steel is connected to cast iron, brass or bronze.

Pipe shops doing such work rapidly accumulate the required templates for making conventional angles and outlets in the usual pipe sizes. Likewise many workmen become very handy in making unusual joints by cut-and-fit. Where special angles, as shown in Fig. 8, or intersections off center are desired, especially where close clearance or dimension is encountered, it would ordinarily be cheaper in the long run for the draftsman to work out the intersections by the principles of descriptive geometry, and forward full size developments to the pipe shop for use as templates.

Such a template for a "stove-pipe angle" is indicated in Fig. 9. It will be noted that the working surface is the *outside* of the pipe,

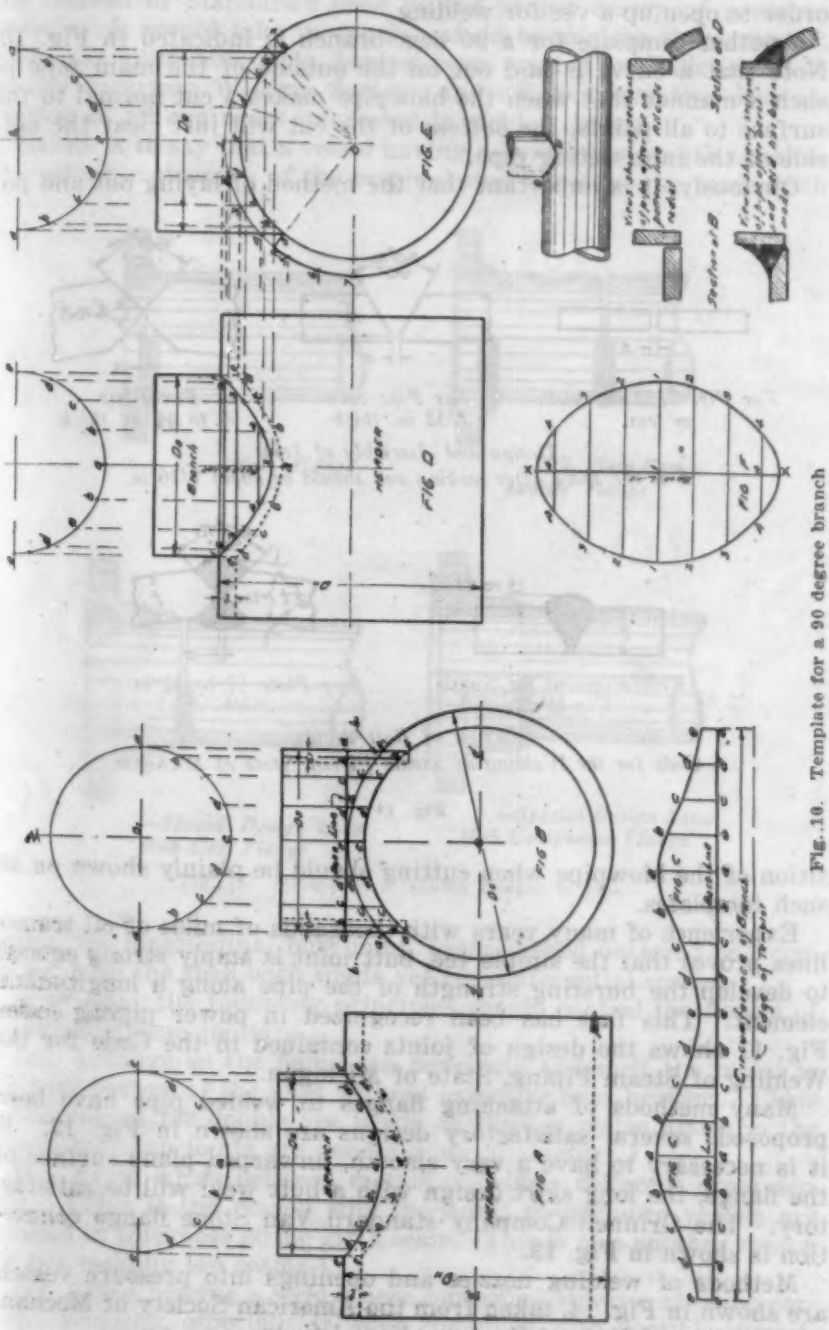
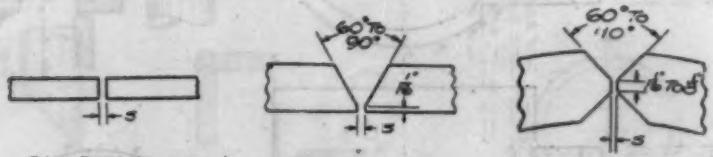


Fig. 10. Template for a 90 degree branch

the blowpipe makes first a miter cut, and then makes a second cut on each leg at a continually varying angle to the miter plane in order to open up a vee for welding.

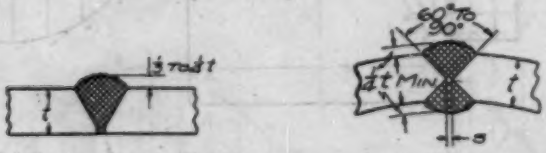
Another template for a 90 deg. branch is indicated in Fig. 10. Note that a curve is laid out on the outside of the main pipe in such a manner that when the blowpipe makes a cut normal to the surface to all points, the *bottom* of the cut will just clear the outside of the intersecting pipe.

Obviously, it is important that the method of laying out and po-



For Pipe 7/32 in. thick. or less. *For Pipe over 7/32 in. thick.* *For Plate ½ to ¾ in. thick.*

Design and Assembly of Joint
S is the space after tacking and should be about 1/16 in.



Reinforcement on Single Vee Weld. *For Plate ½ to ¾ in. thick.*

Design of Butt Welds.
Code for the Welding of Steam Piping, State of Michigan.

Fig. 11

sition of the blowpipe when cutting should be plainly shown on all such templates.

Experience of many years with thousands of miles of oil transit lines proves that the simple vee, butt joint is amply strong enough to develop the bursting strength of the pipe along a longitudinal element. This fact has been recognized in power piping codes. Fig. 11 shows the design of joints contained in the Code for the Welding of Steam Piping, State of Michigan.

Many methods of attaching flanges to welded pipe have been proposed; several satisfactory designs are shown in Fig. 12. If it is necessary to have a very smooth, unwarped plane surface of the flange, the long skirt design with a butt weld will be satisfactory. The Grinnell Company standard Van Stone flange connection is shown in Fig. 13.

Methods of welding nozzles and openings into pressure vessels are shown in Fig. 14, taken from the American Society of Mechanical Engineers' Unfired Pressure Vessel Code.

Pressure Vessels

A great mass of very valuable information can be drawn from the Bureau of Standard's tests on the proper design of pressure vessels. It would take us too far afield to analyze these results. They are quite accessible, having been printed in Bulletin No. 5 of the American Welding Society, and well warrant the close attention of all engineers interested in welded design.

Suffice it to say that a vessel having a bursting strength equal to the ultimate strength of the original steel sheet can be made with

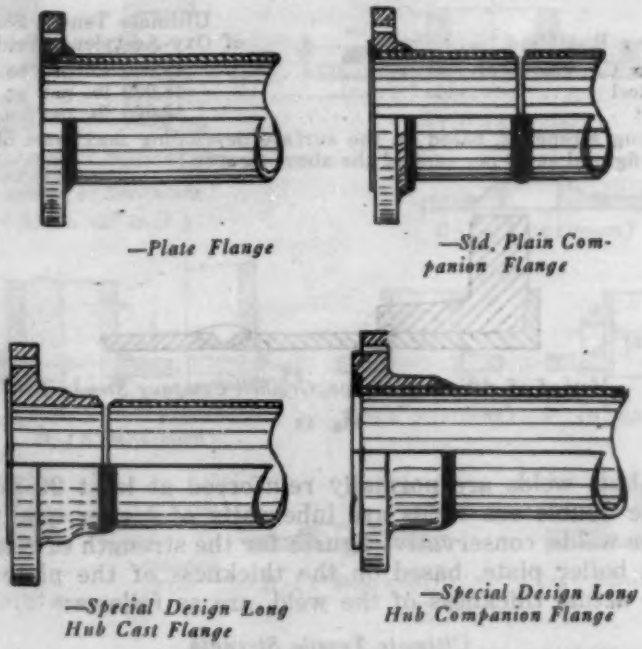


Fig. 12. Method of attaching flanges to pipe

double vee longitudinal butt joint, heads dished outward and connected with the shell with single vee circumferential seams.

In general, the following principles should control the design of all oxy-acetylene joints:—

(a) Arrange so the flame can penetrate and melt the metal to the very bottom of the joint without excessive over-heating. (This is the reason for double vee welds on thicker plates and also the reason why lap joints are generally unsatisfactory.)

(b) Avoid welds between metals of widely different cross section. (This is the reason why the heads of pressure vessels are reduced in thickness at the girth seam. This is also another reason for not welding lap seams.)

(c) Avoid placing a weld where compound stresses must be carried. Bending, especially if when combined with possible impact,

is to be avoided. Avoid especially places where a slight movement will induce much splitting or prying action.

(d) In the layout, avoid intersections of welds meeting as a cross. (It is especially difficult to avoid overheating where four seams join.)

As to allowable strengths:

Ample experience is now available to show that a competent, tested workman, welding under adequate supervision and with good materials and equipment, will be able to produce weld metal consistently which has the following tensile strength:

Welding Rod Used	Ultimate Tensile Strength of Oxy-Acetylene Welded Metal
Plain Low Carbon Steel	43,000 lb. per sq. in.
Nickel Steel	48,000 lb. per sq. in.
High Test	50,000 lb. per sq. in.

(Shearing strengths, based on the surface developing maximum shear, can be safely figured at 80 per cent of the above figures.)

Method of Attaching Flange, Grinnell Company Standard

Fig. 13

Since butt welds are normally reinforced at least 20 per cent, and since double vee welds are inherently of higher quality than single vee welds, conservative figures for the strength of reinforced welds in boiler plate, based on the thickness of the plate rather than the actual thickness of the weld, are as follows:

Ultimate Tensile Strength

Welding Rod Used	Single Vee Oxweld	Double Vee Oxweld
Plain Low Carbon Steel	45,000 lb.	52,000 lb.
Nickel Steel	50,000 lb.	58,000 lb.
High Test	52,000 lb.	60,000 lb.

The above figures are based on a very large number of tests, published and about to be published, taken from the work of over a hundred welders of ordinary ability working in various shops throughout the country. It is therefore believed that they may be duplicated with ease at any time and place where it is desired to do so.

There are those, of course, who would exclude welded joints from all important construction. Such people disregard our accumulated experience with chain and chain cable. For centuries chains have been used wherever the utmost of strength, toughness and reliability is required. Results have been so uniformly satisfactory that today the heaviest loads are hoisted, and the biggest

ships ride safely at anchor, with chain cable; each link having a weld!

One is tempted to rest the argument with that simple statement, were it not necessary to harmonize it with the fact that welds made in a blacksmith's forge are quite variable in quality. The latest edition of Johnson's "Materials of Construction," the stand-

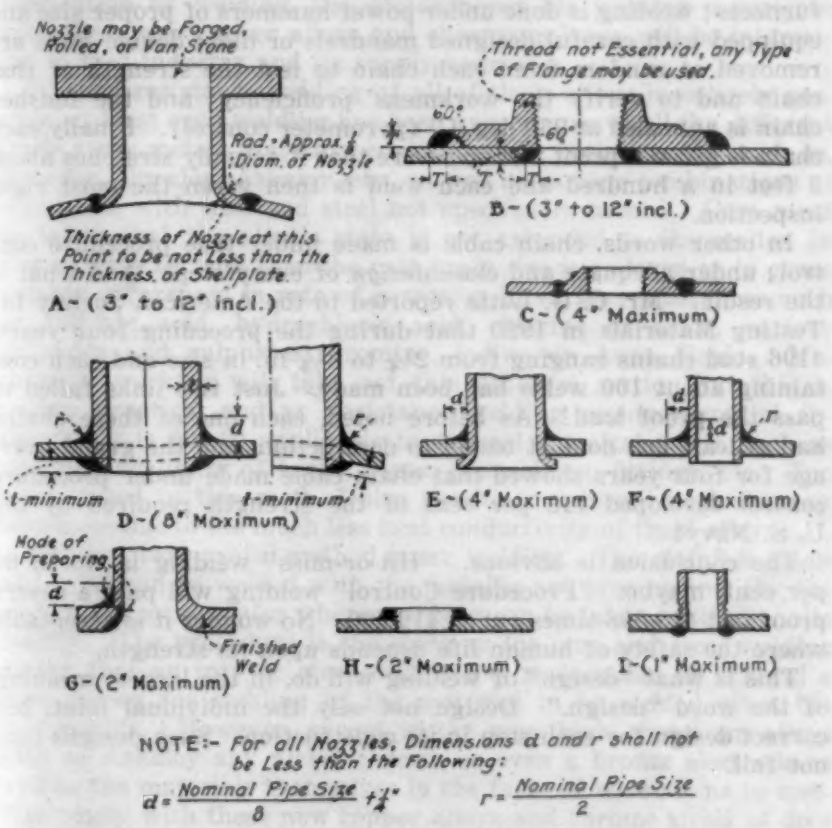

Nozzle may be Forged, Rolled, or Van Stone
Rad.=Approx. ⅛ Diam. of Nozzle
Thickness of Nozzle at this Point to be not Less than the Thickness of Shellplate
A-(3" to 12" incl.)
Thread not Essential, any Type of Flange may be used.
60°
60°
B-(3" to 12" incl.)
C-(4" Maximum)
t-minimum
t-minimum
D-(8" Maximum)
E-(4" Maximum)
F-(4" Maximum)
Mode of Preparing
Finished Weld
G-(2" Maximum)
H-(2" Maximum)
I-(1" Maximum)
NOTE:- For all Nozzles, Dimensions d and r shall not be Less than the Following:
d = Nominal Pipe Size / 8 + ¼"
r = Nominal Pipe Size / 2

Fig. 14. Method of welding nozzles into pressure vessels

ard college text on strength of materials, contains the following on page 607:

"On account of the difficulties encountered in welding, the strength of forge-welded joints in wrought iron is likely to vary from 30 to 100 per cent of the strength of the parts joined. With the most careful hand welding Kirkaldy reports the average efficiency of joints in round tie rods 1½ to 3⅛ in. in diameter as 60 per cent."

Such low strengths are undoubtedly due not to an inherent impossibility of getting a sound weld in wrought iron, but to the fact that each smith is a law unto himself; his work is seldom or never

tested in a scientific manner; and his tools and skill may be entirely inadequate for the work.

Contrast this with the methods in use at the Boston Navy Yard, where chain cables for our warships are made. The material is Grade A, double refined wrought iron, purchased under the most rigid specifications; the joints or "scarfs" are prepared systematically in special machinery; the heating is done in well designed furnaces; welding is done under power hammers of proper size and equipped with careful designed mandrels or dies; double links are removed at random from each chain to test the strength of that chain and to verify the workmens' proficiency; and the finished chain is annealed at 950 deg. C. (pyrometer control). Finally each chain is given a proof test so severe that it actually stretches about 5 feet in a hundred and each weld is then given the most rigid inspection.

In other words, chain cable is made under true procedure control; under adequate and close *design* of every step. And what is the result? Mr. C. G. Lutts reported to the American Society for Testing Materials in 1920 that during the preceding four years, 4196 stud chains ranging from 2¼ to 3¼ in. in size and each containing about 100 welds had been made. Just two links failed to pass the proof load! As before noted, each one of these chains had at least one doublet tested to destruction, and the grand average for four years showed that chain cable made under procedure control developed 112 per cent of the strength required by the U. S. Navy!

The conclusion is obvious. "Hit-or-miss" welding is worth 60 per cent, maybe. "Procedure Control" welding will pass a severe proof test 419,598 times out of 419,600. No wonder it is acceptable where the safety of human life depends upon its strength.

This is what "design" of welding will do, in the largest meaning of the word "design." Design not only the individual joint, but correct design for each step in its construction. Such designs cannot fail.

Electric Welding the New Stainless Steels*

C. J. HOLSLAG†

The chemical industry is very much interested in the new non-corroding or stainless iron and steels for special containers, piping and tanks and as this industry has become used to the ease of fabrication by welding, the writer hopes his welding experience with these new copper alloys and chromium irons will be interesting to that industry and its supply sources.

Electric resistance welding of all of these alloys is entirely possible, at least such welding has been very simple of all the different trade name metals that have come to public notice to date such as, Everdur, Duraloy, Askaloy, etc., as well as various combinations of chromium with iron and steel not specifically named. Care must be taken that the plastic state is not extended to the molten in this process because then the cast grain size is so large as to cause notable differences in rate of corrosion in various substances such as sulfuric acid, hydrochloric acid, chlorine or acids, various chlorides and sulphates, bromine, iodine or Aqua Regia. Mechanical working will take out this different section but this is seldom practical and as Resistance welding requires special apparatus it is not so applicable to general chemical work, such as making and lining of tanks, pipes, connections, fittings, etc. Too much speed in this method also results in internal explosions or blowholes due to the much less heat conductivity of these alloys.

Another very useful method is arc welding. The stainless steels and irons can be welded with the metallic arc process and (by the carbon arc process also where warping can be taken care of) quite readily. The procedure is the same as for iron and steel welding except that an iron or steel electrode is useless and in general a wire drawn for welding of the material to be welded gives the best results. However, except in the very high chromium alloys such as Askaloy any nickel chrome or even a bronze electrode as well as the materials themselves in the form of wire seems to combine nicely with these new copper alloys and chrome steels as does a standard combination of Nickel Chrome known as SAE 3030. Of course, combinations of chromium with iron or steel or nickel and copper alloys have been known to the electric industry for years and the action of slowing down conductivity has been capitalized. In welding, the action of slowing down heat conduction with consequent liability to warpage and the marked increased heat retentiveness is sure to be noted and must be reckoned with in advance for successful work.

In welding by the electric arc process the surface of the steel adjacent to the weld is of a necessity raised to a high temperature for a sufficiently long time to have quite a serious physical effect

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†Chief engineer, Elec. Arc Cutting and Welding Co.

upon the metal. Repeated layers have a refining effect on the metal adjacent to the weld where refining can be done by heat treatment. The chilling effect of the surrounding metal is sufficiently rapid to trap all the various elements in solution. Therefore hardening is likely with those steels that are sufficiently rich in carbon to produce hardness.

Stainless steel containing about 12 or 13 per cent chromium and low carbon, about 0.10, or 0.15 carbon is liable to be hardened from the high temperature of the welding. In welding, stainless iron is raised to varying temperatures from melting point to temperatures below 1650. Where the temperature exceeds 1900 to 2000 deg. the material is apt to be a little softer because an austenitic condition is readily produced. Under these circumstances and dealing with a single deposit there will be a hardened strata in the non-welded portion of the sheet situated about $\frac{1}{8}$ in. away from the deposited metal. Where the grain size is maximum, that is adjacent to the weld, it is often soft because it is austenitic as sufficient of the carbon has been burned out to prevent hardening.

High chromium steels are very prone to grain growth, which grain growth is not capable of refinement by heat treatment. In depositing the second layer, the layer that is austenitic will have been reheated to a less high temperature causing this area to become hard and the layer underneath this, which was originally hard due to the first deposit, will have been drawn so that it is now sorbitic or troostitic.

We are now up against a very troublesome situation. The austenitic area arising from the first layer of deposit has now been hardened due to the heat from the second layer deposit and we are starting off with an initially enlarged grain size. The weld is fairly strong but the area adjacent to the weld is very brittle and fairly hard. The only way in which the situation can be helped is by subjecting the whole welded area to a heat treatment, heating to about 1450-1500 deg. fahr. and fairly slowly cooling. This will cut out the hardness but not remove the brittleness from a very enlarged grain size.

The deposited layer which is presumably the same material as the stainless iron and stainless steel will have a comparatively fine grain size. The reason for this is that you are dealing with a small casting effect and the cooling of the liquid metal is so rapid and the weld so full of impurities producing the necessary nucleii for small crystal size. The first layer deposited by the welding rod will, of course, have its grain size raised by subsequent second and the third depositions.

The only way in which stainless iron and stainless steel may be successfully welded by the electric arc welding wire method is to use an analysis that is incapable of being hardened no matter what temperature it may be raised to, and, secondly, an analysis that has some retardation properties to speedy enlargement of

grain size. The use of silicon in rustless iron will impart such properties to the alloy. At the present time a high chromium, about 16.50-18.50 per cent chromium, and low carbon-silicon alloy is the only one that is capable of being successfully welded by the aforementioned methods, without the difficulties that are encountered because of hard, brittle welds. It is important to use a welding wire made of about the same material.

The use of nickel in stainless steels only adds to the difficulties. The low chromium, about 12-14 per cent chromium, comparatively silicon free alloy under the name of rustless iron is particularly difficult to weld because of insufficiency of chromium. It is too low in chromium to produce the necessary stain and rust resisting properties after the arc process has reduced the content due to burning, it has very little heat resisting characteristics, and the chromium is sufficiently low to produce hardness with small amounts of carbon. Higher chromium such as more than 16 per cent will overcome to a very large degree the first two objections and will obviate the third.

Under these circumstances the tendency is to use the higher chromium, low-silicon iron, which I believe is obtainable commercially. In welding either of these two grades of material welding wire should be used that is of the same analysis as the sheet and to be successful in depositing such material welding wire should be slag covered.

It seems that the A.C. arc is best for this welding, but D.C. can be used in which case the work should be made negative and the electrode positive. In either case the highest voltage that the machine will give up to a maximum of 100 volts, the better will be the weld. If using D. C., a heavier slag coating will be needed and the higher voltage will be required. Wire about ⅛ in. in diameter is far better than using wire ¼ in. in diameter—3/16 is sometimes satisfactory but is apt to generate too much heat. In welding alloy irons or steels no matter what the analysis it is best done when the welding wire is about ⅛ in. in diameter, or not more than 5/32 in. The used strips cut from the material is impractical except with the carbon arc process.

The use of high voltage is essential for two reasons, the work can be more steadily controlled by a strong arc, and secondly alloy steels, particularly those of the stainless variety, have a high electrical resistance, therefore the amount of energy required is comparatively large.

If large wire is used, such as ¼ in. or even 3/16 in. in diameter, there is a tendency for the weld to blow driving away the deposit and producing so much heat that holes are left into the work.

The distance between the electrodes grip and the arc end should be no longer than about 10 in., otherwise the resistance of the wire will cause it to heat to such a temperature that more welding rod will flow off than can be deposited.

For ordinary iron and all steels and monel metal results are about the same with either direct or alternating current; for bronzes, especially those with high zinc, brasses and very thin sheet metal, direct current is best, polarity reversed. For stainless steels, nickel and chromium alloys, semi-arc process for cast iron and Nickel spotting, lead burning, and cutting the alternating current arc is best.

Arc Welded Jigs and Fixtures*

E. VOM STEEG, JR.†

While arc welding was originally used more for repairs and maintenance, it is today used to a considerably greater extent as a production method. When so used and quantity production is desired it pays to make up jigs for holding the work during the process of assembly. The jigs themselves are made by the use of commercial structural shapes, which are arc welded together.

Fig. 1. Jig and assembly of arc welded small truck wheels for movable switchboard panels

Fig. 1 shows the method of assembling the small arc welded wheels which are used on the various welded trucks and movable truck type switchboard panels. You will note that this wheel consists of a felly and a rim, both of which are shown at the right of the photograph. Once in the jig the rim is tack welded to the felly at four different points around the circumference, after which it can be removed from the jig and the welding operation completed.

Fig. 2 shows the assembly and jig used in making the steel fingers used in holding the punchings in the welded stator frames for large generators and motors. It might be well to state here

*Presented at February Meeting, New York Section, A. W. S.

†Arc Welding Specialist, General Electric Co.

that a large number of these frames are now being made entirely by arc welding.

Fig. 3 shows a completely welded stock room truck together with the various parts which go into the building of the truck. These trucks are so constructed that the under part is all inside of the steel sides of the upper compartment or that a series of these trucks may be placed side by side quite closely together and any

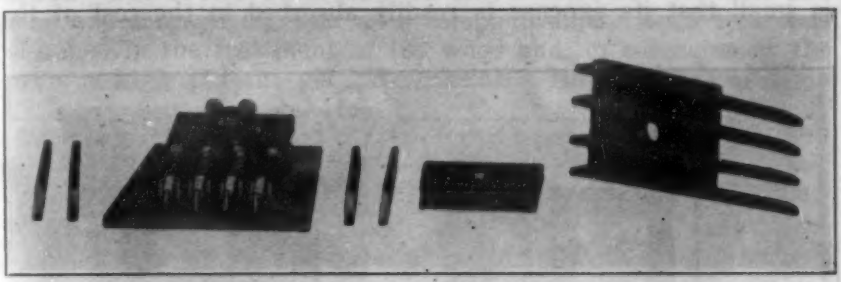


Fig. 2. Assembly and jig for holding laminations in electrical machines

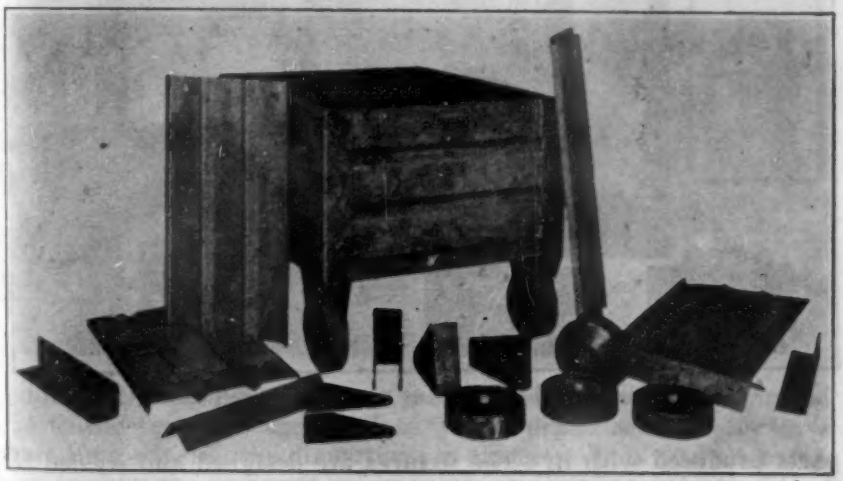


Fig. 3. Welded stock room truck and parts from which it is made

one of them may be easily pulled out without in any way interfering with the position of the remaining trucks adacent to it. This method affords great convenience in the stock room.

These potographs show only a few of the possibilities of the use of jigs in handling production welding and give an idea of what can be accomplished with their use.

In addition to the jigs shown in the preceding illustration the arc welding process is also very well adapted to the making of jigs and fixtures for use in a bulldozer. A great many times it is necessary to make up a number of pieces of the same shape and size,

but the quantity is not great enough to warrant the cost of special permanent tools being made for their manufacture. These jigs can be very economically made by arc welding. A number of these are shown in Fig. 4.

If there is no possibility of any immediate further use for these jigs they are scrapped after having served their purpose. This eliminates the necessity of providing racks and storage for an accumulation of these jigs and fixtures. The cost of the fixture is so small that its expense is readily absorbed in the cost of the

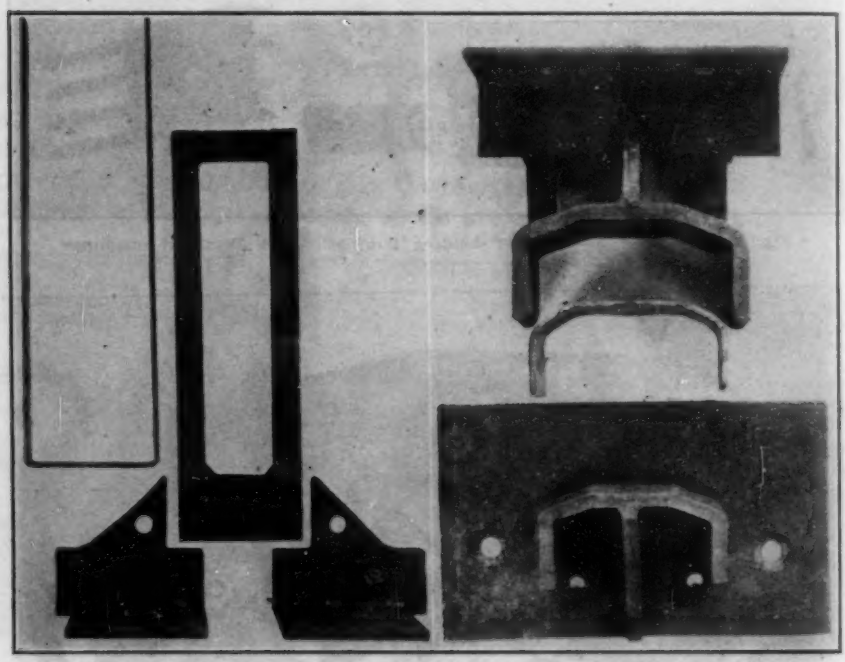


Fig. 4. Arc welded die for forming steel parts in bulldozer

parts produced with it. The fixtures are designed and welded by the men in the blacksmith shop, no special eigineering being required. To illustrate the saving affected by use of fixtures of this type, we had a case where a cast iron fixture cost $100 and an arc welded fixture designed and built for the same work cost only $15. Against the cast iron fixture, of course, was charged engineering and drafting, pattern making, casting and some machine work. The arc welding fixture simply required the cutting out of the pieces of steel with an oxy-acetylene torch and welding them together in the proper form with the electric arc.

Where a formed part is required to meet nearly approximate dimensions these arc welded fixtures may be employed with great advantage and economy.

Welding as Applied to the Automotive Industries

JOSEPH W. MEADOWCROFT†

During the early days of the fabrication of automobile bodies very little was known concerning the various methods of welding metals. The bodies were designed and constructed of wood and glued and screwed together as a complete unit. Much time was consumed in the treatment of the wood and, in consequence, the cost was high and the production small. Much trouble was en-

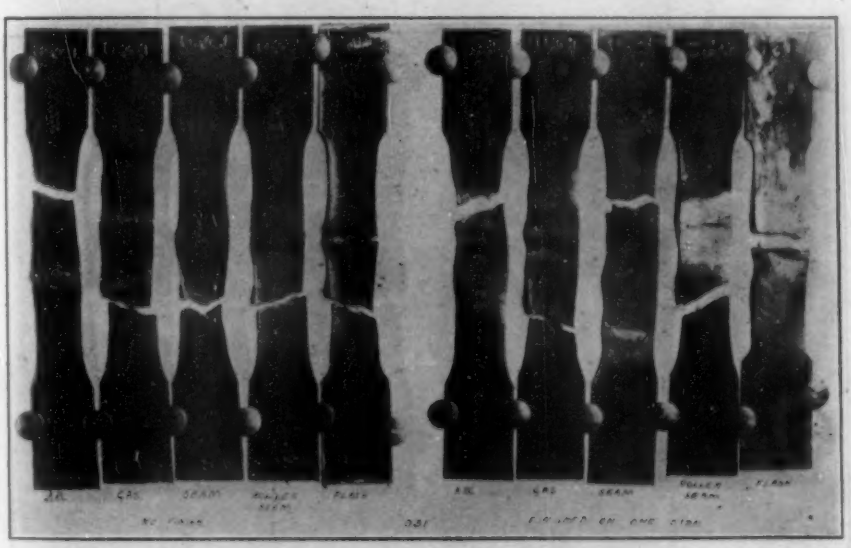


Fig. 1. Test samples cut from welds made by electric arc, gas and electric resistance methods. Note all breaks are outside of welds

countered by the manufacturers producing bodies with this method due to the fact that the wood sections warped considerably in a short time, causing the dimensions to change. This made it necessary to shim the bodies at many points on the chassis so that they could be placed in proper alignment.

This method of construction was improved upon after a score of years by covering the wooden structure with sheet metal; and although this was a decided improvement from a surface standpoint and improved the painting conditions, it did not strengthen the bodies, nor did it solve the problem of producing bodies in large quantities at a low cost and still produce a body which would be safe for the public to use. When the first bodies were covered on the surface with sheet metal it was necessary to use a large number of coats of paint to cover the metal defects. However, much credit is due the metallurgists of the various automobile companies

†Edward G. Budd Manufacturing Company, Philadelphia-Detroit.

throughout the country who worked hand in hand with the mill men of the steel mills, bringing about a marked improvement in the surface of the sheet metal.

All the success, however, cannot be attributed to the metallurgists, as improvements were made from time to time by the designers, die makers, press men, etc. The whole has been a gradual development to which all concerned have contributed.

In the course of forming the stampings much trouble was encountered with the metal and this caused the various engineers to search for a method of fabrication whereby the pieces or stampings could be made in small sections, thereby eliminating break-

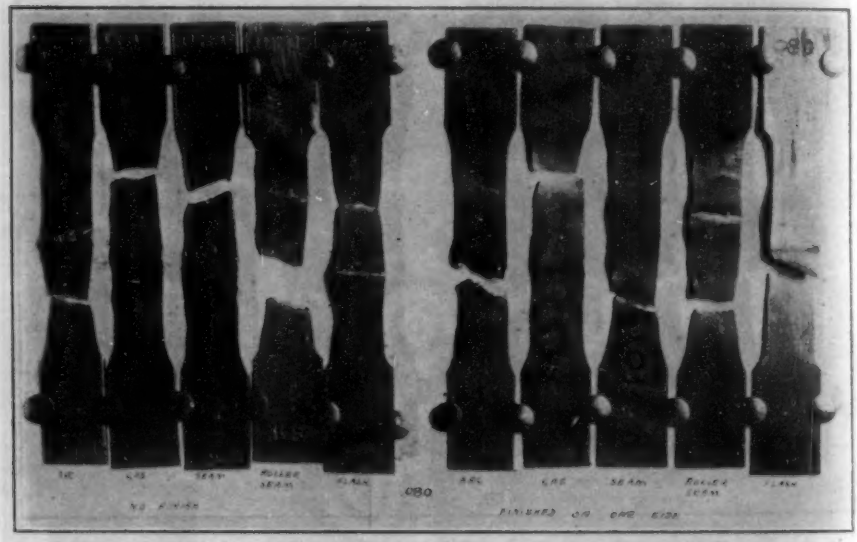


Fig. 2. Test samples cut from welds made by electric arc, gas and electric resistance methods. Note all breaks are outside of welds

age. This would result in a large saving in steel and reduce the die cost in many instances.

The first welding method that was applied successfully was the oxy-acetylene process. It was used in the assembly of three-piece tonneaus, three-piece cowls and door sections. This, although a great improvement, increased our troubles as it gave us the expansion and contraction problem to solve, but it was finally worked out successfully and oxy-acetylene welds were made on the above parts in such a manner that they proved to be safe and commercially sound. The welds were originally made on the outside surface of the metal joints at the joints, but after having some difficulty in finishing them—and still retain sufficient strength on the light gages of metal to stand the stresses and strains placed on an automobile body—it was decided to weld on the inside of joints, trip hammer the joints at weld and solder them on the outer sur-

face to eliminate any defects from the improper fusion of metals or porous spots. These defects were caused by the following conditions in the oxy-acetylene welding operation:

(a) Operator using an oxidizing or carbonizing flame.
(b) Operator using a poor quality of welding wire.
(c) Operator using a larger tip than specified for the gage metal to be welded.

Fig. 3. Arc weld shaded portion is area covered by microphotograph. Dotted line indicates junction of welded pieces. 50X

(d) Operator using an improper gage of filler rod or wire.
(e) Impurities of gases.
(f) Inefficient operator.

These difficulties were overcome and much was accomplished in producing stampings with this method. However, after using this method of fabrication for ten years or more, the arc butt (flash) and roller method were developed, and although the arc method is only used in a few cases for light gage sheet metal it is being applied very successfully on heavier gages automatically. The arc welding of light gage sheet metal is still in the development stage and the various welding authorities are working on a filler material which will give the welds the ductility required. Butt

(flash) welding has met with success, although the maintenance of keeping copper dies in their proper alignment has made it an expensive method; yet where solder is used on the outside surface of weld it reduces the cost of fabrication of stampings. In some cases the flash welds are ground inside and outside of joints and then trip hammered, causing an extra operation over the oxy-acetylene method. However, the flash welding is so much more

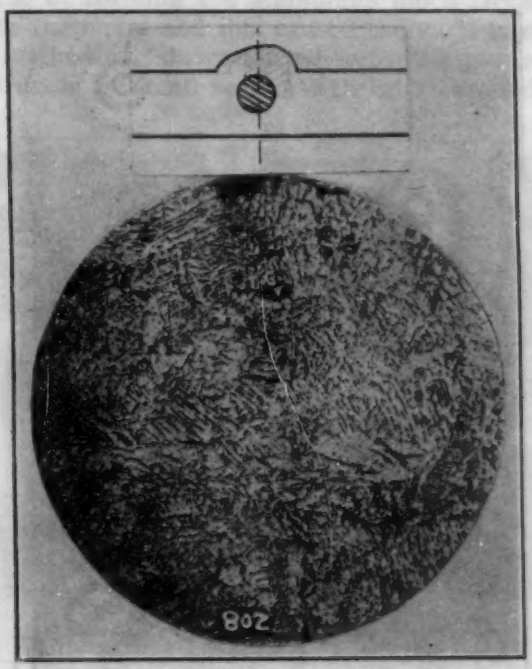
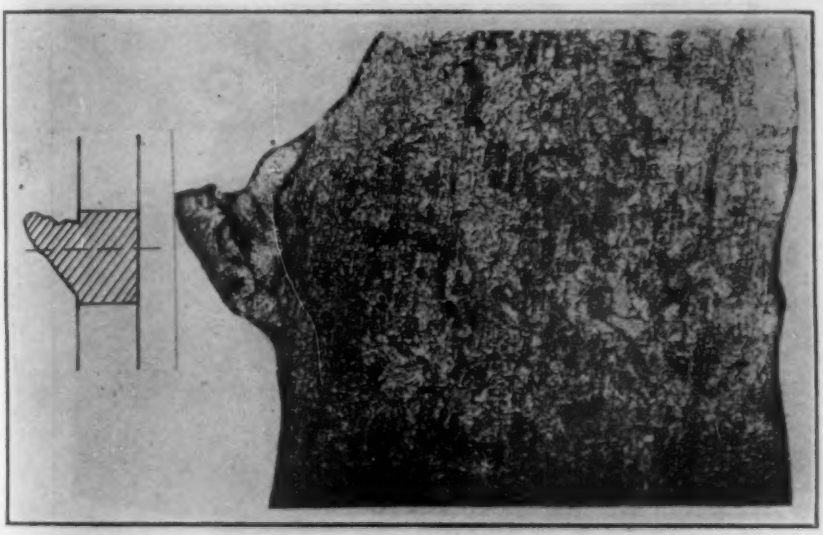


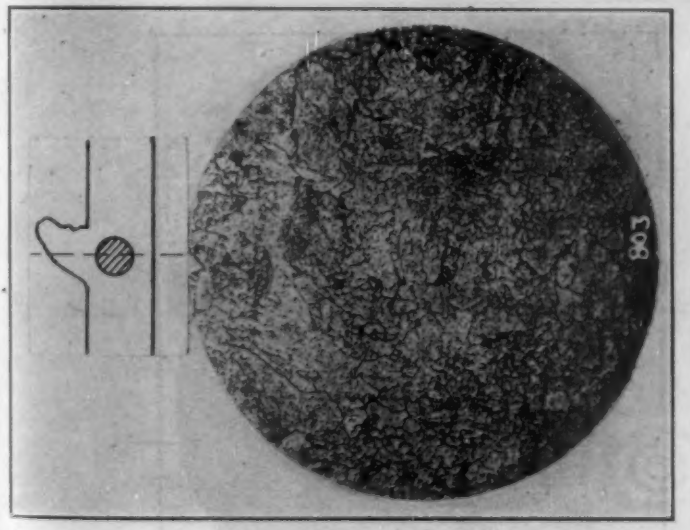
Fig. 4. Same as Fig. 3, except magnified 100X

economical, from a welding standpoint that it more than offsets this one operation. Roller welding is being developed to weld the gages of sheet metal which are so commonly used on automobile bodies, and although more or less in its infancy, it will no doubt be a coming factor in the fabrication of sheet metal commodities.

A large number of small parts or sections of the bodies are being butt welded, flash welded, arc welded and oxy-acetylene welded very successfully, yet the more economical welding method of all is the electric spot welding. Many estimators figure that it is much cheaper to make many stampings in several pieces and weld same together; and although there are many items on which savings can be accomplished in this manner on small production work, yet in many cases where the production is large it is much more economical to omit any method of welding not necessary because the cost of welding is too expensive, but the finishing cost is entirely too high.

Metal up to this time has improved considerably, but there are still many conditions which cause worry and trouble in forming same on dies, either on a double-action or single-action press. The property of spring back makes the problem of producing stampings



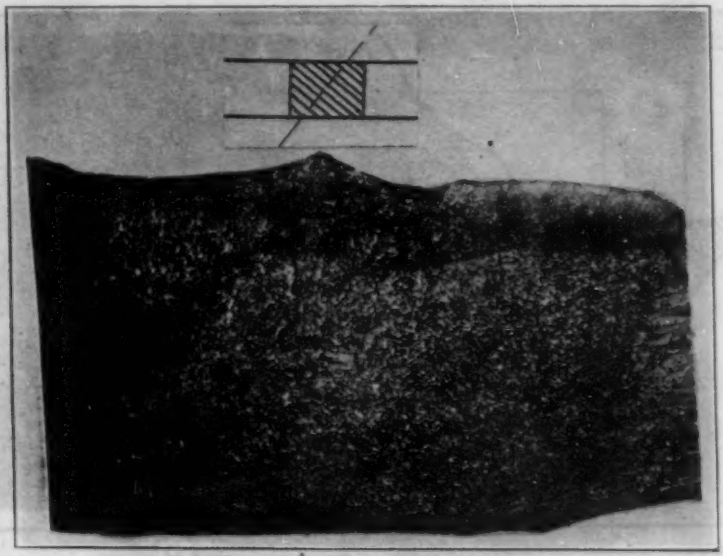


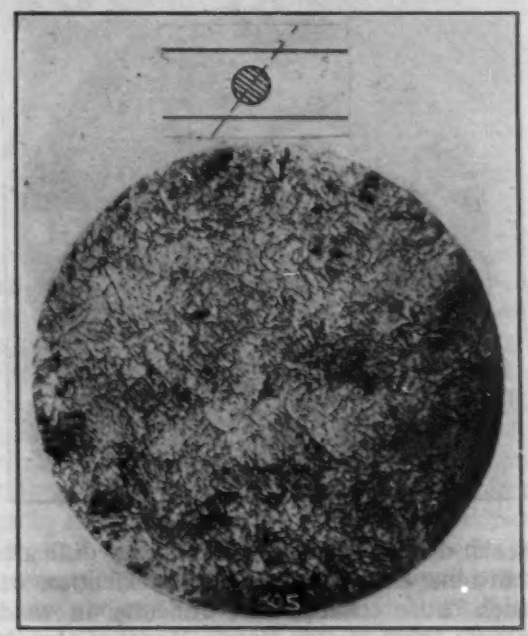
Figs. 5 and 6. Gas weld. Shaded portion is area covered by microphotograph. Dotted line indicates junction of welded pieces. Right hand 50X. Left hand 100X

to align with each other before welding a very difficult one. There are other conditions entering into the fabrication of automobile stampings which cause considerable difficulty in welding, but we will not enumerate them at this time. Many of the above troubles are overcome through the use of spot welding, as it is possible to assemble stampings in jigs and fixtures, allowing the proper di-

mensions for expansion and contraction with much less difficulty than with any other method of welding.

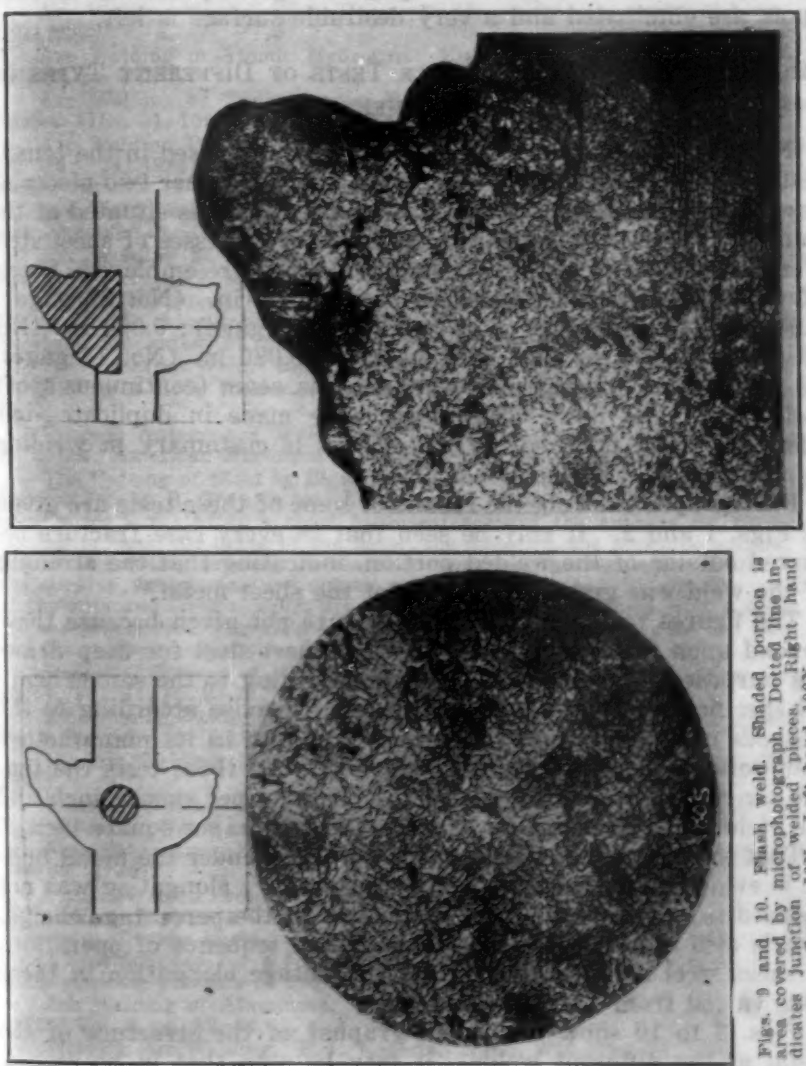
With the composite body this method is more or less limited and it is impossible to make a complete welded unit, but on the modern





Figs. 7 and 8. Seam weld. Shaded area is portion covered by microphotograph. Dotted line indicates junction of welded pieces. Upper figure 50X. Lower figure 100X

all-steel bodies it is possible to weld on the interior as well as the exterior, making a complete welded unit. All methods of welding, thermit excepted, are used in the manufacture of all-steel bodies, and each particular method is used from an economical as well as



Figs. 9 and 10. Flash weld. Shaded portion is area covered by microphotograph. Dotted line indicates junction of welded pieces. Right hand figure 50X. Left hand 100X

a productive standpoint. No solder is used on all-steel bodies, and the welded joints do not break open, nor do the metals rub upon each other. Thus squeaks and noises which are so common on a composite body are eliminated. In sections of the body where spot welds are made on beads, the spot welds are made in such a manner as to cause part of the weld to project or protrude above

the surface of the surrounding metal, forming a small teat or projection at the weld. . The weld is so made that this projection protrudes from the surface to be finished, that is, the surface in which any low spots are objectionable as stated heretofore. Where this surface is finished off, either by grinding or polishing, all low spots are eliminated and a very desirable surface is left.

Microphotographs and Tensile Tests of Different Types of Welds in Sheet Steel

Figs. 1 and 2 show the form of test specimen used in the tensile tests. The specimens were made by welding together two pieces of sheet steel and then machined so that the weld was situated at the middle of the 2-in. gage length. Different thicknesses of sheet steel were used and different methods of welding were employed. Steels of the following thickness were used: 0.031 in. (No. 22 gage); 0.043 in. (No. 19 gage); 0.050 in. (No. 18 gage); 0.062 in. (No. 16 gage); 0.074 in. (No. 15 gage), and 0.080 in. (No. 14 gage). The methods of welding used were arc, gas, seam (continuous spot) roller seam and flash. Specimens were made in duplicate—one specimen being polished on one side as is customary in welding joints in all-steel automobile bodies.

Photographs showing the results of some of these tests are given in Figs. 1 and 2. It may be seen that in every case fracture occurred outside of the welded portion, indicating that the strength of the weld was greater than that of the sheet metal.*

The figures for the tensile strength are not given because these depend upon the types of sheet used. Sheet steel for deep drawing purposes, although usually made according to the same chemical specification, may vary in physical properties according to the methods and sequence of operations employed in its manufacture (hot rolling, cold rolling, annealing, etc.) In these tests the tensile strength varied from 40,000 to 60,000 lb. per square inch and the yield point varied from 25,000 to 45,000 lb. per square inch.

That the welding of the specimens did not render the metal brittle is evidenced by the fact that the percentage elongation was not reduced to a low figure. (The magnitude of the percentage elongation is also influenced by the methods and sequence of operations in sheet steel manufacture.) The percentage elongation in these tests varied from 11.0 to 25.0.

Figs. 3 to 10 show microphotographs† of the structure of the metal at the different welds. It may be seen that in no case is there a line of demarcation at the junction point, indicating that complete fusion has really taken place.

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*It should be pointed out that this increase in strength is not due to the inherent strength of the metal included in the weld, but to the greater cross sectional area of the welded portion. The fractures occurred outside of the weld for all thicknesses of metal, although photographs of only the thinnest and thickest specimens are shown.

†The microphotograph of the roller seam weld is omitted because the structure would appear essentially the same as that of the continuous spot weld. Tests made by Joseph Winlock, Metallurgist, E. G. Budd Mfg. Co.

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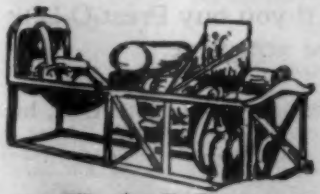

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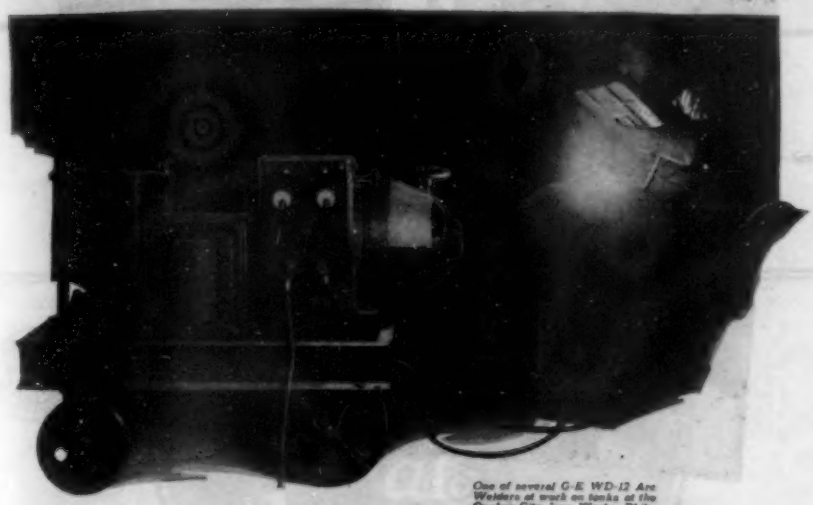

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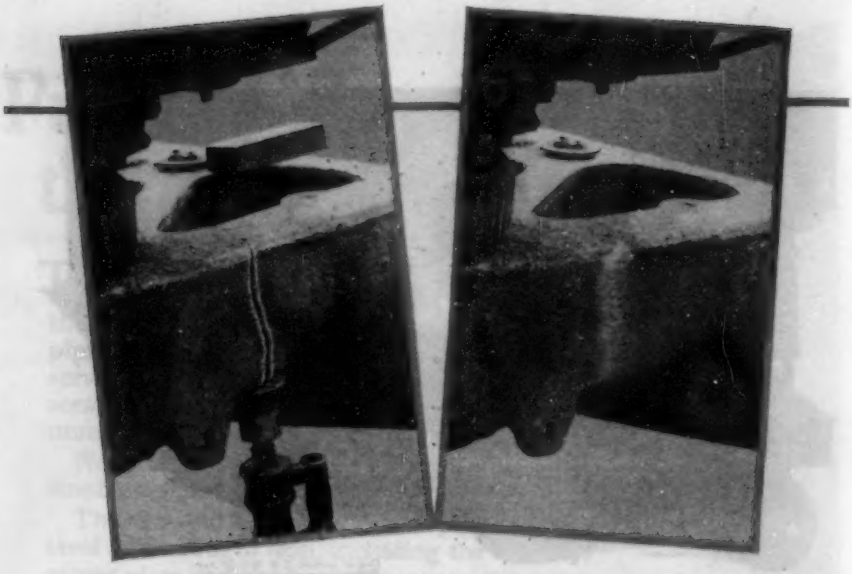

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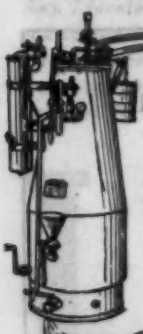

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